TORNADOES

FINLEY

TORNADOES.

WHAT THEY ARE AND HOW TO OBSERVE THEM;

WITH PRACTICAL SUGGESTIONS FOR THE PROTECTION

OF LIFE AND PROPERTY.

BY

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The important information set forth in this book is the result of many years of labor and the examination of more than five thousand storms. Ascertained facts have been taken as the basis of every statement, and it is believed that, while further investigation may add truth to truth, it will only set more strongly the seal of authority upon what is here presented concerning the special characteristics of tornadoes and the great dangers which accompany them, augmenting the practical knowledge thus far obtained regarding the protection of life and property.

THE AUTHOR.

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BY

LIEUT. JOHN P. FINLEY, U. S. A.

The people of the United States are no longer strangers to that dreaded aerial monster, the TORNADO. A single experience of this awful convulsion of the elements suffices to fasten the memory of its occurrence upon the mind with such a dreadful force that no effort can efface the remembrance of it. The destructive violence of this storm exceeds in its power, fierceness, and grandeur all other phenomena of the atmosphere.

For over two hundred years past the scientific records of this country have furnished information concerning these storms. It is the same fearful story year after year, of destruction and death, and the records are now sufficiently complete to show beyond all contradiction or exception that tornadoes are indigenous to this country. They belong here because our geographical position and the topography of the country are altogether favorable for the conditions which give rise to their formation. No other country in the world is scourged by them as is the United States of America. If our broad expanse of country was cut up by mountain ranges running in every direction, forming a network over the vast plains of the West, and cutting up like a checker-board the great valleys between the Appalachian and Rocky Mountain ranges, then

topographical conditions would intervene and present formidable barriers to the direction and effect of surface currents. These conditions, if they were present, would well nigh rid the country of the funnel-shaped cloud. Fortunately—or unfortunately, we are not to say which—there are no natural barriers to the development of tornadoes in the greater portion of the United States. Their geographical distribution is graphically presented by chart No. 1 (see frontispiece), and the effect of the Appalachian chain of mountains, and that of the Rockies and the Sierra Nevadas over the vast stretch of country west of the 100th meridian (Greenwich) is strongly displayed on the chart and the argument set forth is conclusive.

The populous region of the United States is forever doomed to the devastation of the tornado. As certain as that night follows day is the coming of the funnel-shaped cloud. So long as the sun shines upon the vast regions in the Mississippi and Missouri valleys, there will forever occur those atmospheric conditions which terminate in the destructive violence of the tornado. Nature's laws are unerring in their certainty of procedure, the earth must travel in its orbit about the sun and the seasons must recur in regular sequence as the result of this wonderful periodicity of movement. The earth must revolve upon its axis, and daylight and darkness, heat and cold, must succeed each other with infallible precision. Without these great and regular mutations dependent upon the solar system, atmospheric phenomena would cease altogether. Granting that the solar system must continue intact, we have but to watch and protect ourselves as best we may against the fury of the elements. Ignorance of our surroundings is a most unfortunate plea for those who stubbornly fail to heed the warnings of science. Thousands of people comfort themselves with the thought that as they have escaped in the past, so will they always remain free from danger; but a knowledge of the tornado, and the necessary precautions to be taken for purposes of safety, should be as common and

familiar to the people living in tornado districts as a knowledge of the ordinary methods of extinguishing fire. Every effort should be made to popularize the information on this most important subject.

In spite of all that has been written and published about tornadoes in the press, in scientific journals, and through the Signal Service, much confusion prevails regarding the application of the term and the distinctive character of the storm. This confusion leads to a most unfortunate disregard of certain necessary provisions for safety which should not be neglected by people residing in the tornado districts. Under the head of "wind-storms" there are various atmospheric phenomena, severally designated as tornadoes, cyclones, hurricanes, whirlwinds, waterspouts, hailstorms, and thunderstorms, which are essentially distinct in their characteristics. While they are all seriously destructive in their effects, there are many differences which give rise to modifications in their development which it is of importance to know. All of these storms are more or less destructive to life and property, therefore means of protection should invite the earnest attention of all people.

The coming and going of these storms are as certain as death, yet adequate means of protection for the body and for property are strangely ignored! A practical knowledge of the various kinds of storms known to the United States should be one of the subjects of instruction in our public schools. As the country increases in wealth and population, which it now is doing with wonderful rapidity, the danger to be apprehended from the violence of wind-storms is appalling. Formerly, these violent meteors left no mark upon the treeless and uninhabited prairie, or if passing through the wooded regions there remained but the "windfall" to denote the track of the monster, but now the farm-house and the village dot the plain, and the hardy laborer has forced his way with his family into the depths of the forest. Where, years

before, there were but inanimate objects to mark the fury of the tornado, precious lives and hard-earned property now succumb to its violence. The funnel-shaped cloud with its tail lashing the earth must now pursue a most tortuous course to avoid the farm-house and the mill, the schoolhouse and the church. The best evidences of civilization and material prosperity suffer untold misfortune, and must continue to do so while our earth has an atmosphere and the sun shines upon it.

This state of things, which upon first consideration may cause alarm and discouragement, should upon reflection give rise to courageous efforts in the direction of securing indemnity from loss of property, and establishing provisions of safety for human life. The protection of life and property from fire, shipwreck, and disease has compelled the growth of institutions under State authority which afford a safe and generous indemnification in case of loss ; a similar necessity in the event of destruction by wind-storms must call for the growth and support of similar institutions.

I have previously referred to the necessity of a practical knowledge by the people generally of the various classes of wind-storms, particularly the tornado. It will not be amiss here to give a brief description of those phenomena, point out their differences, and then follow with a special discussion of the tornado.

CYCLONES.

A cyclone is not a tornado, either in the perfection of its development, or in any stage of its formation and progressive movement. The two storms are essentially different. The cyclone possesses the following characteristics: The path of the storm is a *parabolic curve.* It trends northwestward from the West Indies until it reaches parallel 30° N. when it curves to the N. E. and continues in that direction, either at some distance off the Atlantic coast, on its immediate border, or a

short distance inland. The storm finally disappears oceanward in the vicinity of parallel of 50° N. The diameter of its path varies from several hundred to over one thousand miles. At the immediate center of the storm there is a dead calm, a most fatal place for ships to be caught. At no point without the storm's center does the air actually move or whirl in a circle, but there is a cyclonic tendency of the atmosphere about the region of barometric minima, viz.: where the barometer is the lowest. Upon taking a number of points, located here and there in the four quadrants* of the meteoric disturbance, it will be found that in the northeast quadrant the winds vary from southeast to northeast; in the northwest quadrant from northeast to northwest; in the southwest quadrant from northwest to southwest, and in the southeast quadrant from southwest to southeast. The barometer is a very important factor in all calculations bearing upon a determination of the character and approach of the cyclone at *any point* in the parabolic course of the storm. The wind very rarely reaches either an estimated or measured velocity of one hundred miles per hour. The maximum velocity generally ranges from sixty to eighty miles per hour. As a rule there is no sudden, overwhelming dash of the wind, but a gradual approach or increase of movement which eventually culminates in a fierce intensity sufficiently powerful at times to destroy buildings or sink the largest ships. Cyclones occur most frequently in the months from August to November. In the China and Japan Seas this class of wind-storms is called typhoons. In general, as to their place of origin, cyclones form south of the Tropic of Cancer, between the belt of calms and the southern limit of the trade-winds; say, briefly, in the vicinity of 10° N., 50° W. This region coincides with the zone of constant rainfall, where evaporation

* QUADRANT; the fourth part of a circle. In describing wind-storms, etc., it is customary to speak of the area alluded to as divided into four "quadrants;" the northeast, northwest, southwest, and southeast.

is very rapid, cloud formation exceedingly brisk, the air almost constantly saturated with moisture, and heavy condensation a regular feature of the day. Typhoons form south of the Tropic of Cancer and in the vicinity of the Philippine Islands, moving thence northwestward to the Asiatic Coast and then curving to the northeast over the adjacent seas and islands. As to the character of the region in which they form, the same remarks apply as in the case of cyclones.

TORNADOES.

The tornado is truly and invariably a land-storm, which we find possessed of the following prominent characteristics: A path varying in width from a few yards to eighty rods. The general direction of movement of the tornado-cloud is invariably from a point in the southwest quadrant to a point in the northeast quadrant. The tornado-cloud assumes the form of a funnel, the small end drawing near to or resting upon the earth. This cloud, or the moving air of which it is the embodiment, revolves about a central, vertical axis with inconceivable rapidity, and always in a direction contrary to the movement of the hands of a watch. The destructive violence of the storm is sometimes confined to the immediate path of the cloud, as when the small or tail end just touches the earth While, on the other hand, as the body of the cloud lowers, more of it rests upon the earth, the violence increases and the path widens to the extreme limit. The tornado with hardly an exception occurs in the afternoon, just after the hottest part of the day, and generally disappears before the going down of the sun. The hour of greatest frequency is between three and four P. M. A tornado very rarely, if ever, begins after six P. M., but a tornado *commencing* about five P. M. may *continue* its characteristic violence until nearly eight P. M., which only means that the tornado-cloud may be traveling after six P. M. or after seven P. M., but it does not develop, that is, make its appearance for the first time,

after those hours. Without the path of destruction, even to the shortest distances, at times even along the immediate edge, the smallest objects often remain undisturbed, although a few yards distant the largest and strongest buildings are crushed to atoms. At any point along the storm's path, where there is opportunity afforded the tornado-cloud to display its power, the disposition of the débris presents unmistakable signs of the revolving, right-to-left action of the wind. The violence and intensity of the destructive power increases directly as you pass from the circumference of the storm to its center.

Observations with the barometer are of little practical value at any one point, whether made before or after the tornado-cloud has formed or while it is approaching. Such observations will not indicate its approach, however near the position of the instrument to the point of the cloud's inception. The "tornado season" is embraced between March and October. The months of greatest frequency are May and July. There are exceptional instances in a long series of years where tornadoes have been reported in every month of the year. They may, and sometimes do, occur in some of the Southern States during the winter and spring months. Taking the whole United States together and averaging the dates of occurrence for a long series of years (over 200) it is found that the region of greatest frequency embraces the States of Kansas, Illinois, Missouri, and Iowa. Of all the States in the Union, Kansas and Missouri rank the highest in regard to frequency.

HURRICANES.

Although it seems hardly necessary to define the hurricane, it will perhaps be well to state that as here considered it means a straight wind of extraordinary velocity. It may, and frequently does, occur without the accompaniment of any precipitation. On the summit of Mount Washington, White Mountains, New Hampshire, a measured velocity of nearly two hundred

miles per hour has been recorded. On the summit of Pike's Peak, Rocky Mountains, Colorado, a measured velocity has several times exceeded one hundred miles per hour. On the coast of the Carolinas maximum measured velocities have ranged from seventy-five to one hundred and sixty miles per hour. In the Eastern Rocky Mountain Slope and in the Lake Region measured velocities are sometimes recorded ranging between sixty and eighty miles per hour. This storm may be known as the Blizzard of the Northwest, the Chinook of the Northern Plateau, the "Norther" of the Southern Slope and Texas, or the Simoon of the Desert. Hurricanes may occur at any hour of the day or night and in any month of the year. The most violent, however, take place during the spring and autumn. The width of the path of the storm is very irregular and may vary from many rods to many miles. In either case the velocity at all points within the storm's path is not necessarily the same; in fact such a condition never occurs. The duration of the storm is also extremely variable, it may continue for only a few minutes or for several hours, although in the latter case the maximum velocity is not maintained throughout the entire period; on the contrary, there are periods of recurrence alternating with decided diminutions of the highest activity. There are perhaps but few portions of the country altogether free from the possibility of their occurrence. In the low table-lands of mountainous regions, where most of the country is extremely broken, the habitable portions are shielded from the power of violent wind-storms. No surface currents can attain any great velocity in such regions, although on the mountain peaks and elevated plateaus dangerous hurricanes at times prevail.

WHIRLWINDS.

In defining these disturbances it will be best perhaps to recall the occurrence, on a warm, dry day, of the formation of a dust-whirl as it suddenly bursts upon you in the open

street, fairly enveloping your body with fine particles of dirt, straw, leaves, and the like. Whirlwinds suddenly start up from some barren, sandy spot unduly exposed to the direct rays of the sun. Over a small surface thus exposed the air rapidly rarifies, and ascensional currents form which move spirally inward and upward, carrying dust, leaves, straws, and sometimes objects of considerable weight. The whirlwind's path has a diameter of several feet (sometimes rods), and the direction of its course of movement is decidedly irregular, possibly moving toward any point in the compass. On the sandy plains of Arizona, Southern California, and Nevada these phenomena occur with great frequency during the summer months. Columns of whirling sand, sometimes several in a group, move rapidly over the surface. A whirlwind is harmless and generally of but a few moments' duration. In comparing it with the tornado let it be borne in mind that the whirlwind starts from the earth's surface, extends upward and moves onward, not leaving the earth, being solely confined to the region of surface currents, while the tornado forms near the superior limit of the lower regions of the atmosphere and between the upper and lower sets of currents, or the currents prevailing in the upper and lower regions of the atmosphere; the former currents are indicated by the appearance of the fine cirrus* clouds and the latter by the heavy cumulus formations. From this lofty seat of origin the tornado-cloud gradually descends to the earth's surface, increasing rapidly in size and augmenting in power.

WATERSPOUTS.

These disturbances generally form at a considerable height in the air, although at times they seem to ascend from the water's surface; that is to say, there is no visible agent influencing the ascension of the water, but of course in every

* Cirrus clouds are fibrous or woolly-looking. Cumulus clouds are convex masses, piled one upon another. Stratus clouds are spread over the face of the sky evenly or in horizontal layers. Nimbus is a name given to ordinary rain-clouds.

instance the causative power is from above and in the latter case near the water's surface. When I speak of the formation of the waterspout at a considerable height in the air, I mean that the embodiment of the whirl, or the revolving current of air, first appears as a dark cloud of minutely divided particles of water, the result of rapid condensation, of course in the air and therefore above the water. The swift passage of the air in a spirally upward motion over the surface of the water raises it in the form of spray and carries it upward in the center of the whirling cloud, which then presents the appearance of a densely opaque body and conveys an impression to the eye of the observer, that a huge column of water is ascending in the form of a long spout, widening gradually toward the top. There are instances, however, where the force manifested is sufficient to raise a considerable quantity of water several hundred feet in the air. Waterspouts form during periods of excessive heat, generally in the afternoon and at or near the hottest part of the day. In the temperate zone they only occur during summer months. They are of most frequent occurrence in the region of calms between the tropics, but are not altogether strange sights in the Gulf of Mexico and along the gulf stream south of parallel 40° N. In regard to motions they possess both a rotary and progressive action, but in neither do they manifest a permanency of direction. Waterspouts cannot be considered as altogether harmless, for there are instances where vessels have been wrecked by them.

HAILSTORMS

Are peculiar atmospheric disturbances which, in regard to the dimensions of their paths, are next to the tornado the most circumscribed of all storms save the whirlwind. They are characterized by a strange cloud formation and a peculiarity of precipitation unlike any other phenomena in the category of storms. The cloud from which the hail falls is bas-

ket-shaped, with a dark and portentous exterior, a ragged and ominous-looking opening at the bottom, and within a whirling conglomeration of snow-flakes, pellets of snow and ice, partly formed and perfect hailstones, the latter of an almost infinite variety of shapes. The hail-cloud forms between the currents of the upper and lower regions of the atmosphere and moves forward in the plane of these currents, either within or just above the upper limit of the lower atmospheric regions, where it finally disappears and the deposition of hail ceases. The path of the storm, as indicated by the distribution of the hailstones, is at times very narrow, although the range of width is decidedly inconstant, varying from one to fifteen miles. The hailstorm travels quite rapidly, from thirty to fifty miles per hour, and the length of its path is even more variable than the diameter, ranging as it does from ten miles to two hundred or more. The direction of the course pursued by the storm is always from some point west to some point east. It may be from northwest to southeast or from southwest to northeast. Hailstorms may occur at any time of the day or night, although they are most frequent in the afternoon, just after or near the hottest part of the day. They are most prevalent in that region of country embraced between the parallels of 30° and 50° N. South of parallel 30° N. hailstorms are of rare occurrence at the level of the sea, but at the height of one or two hundred feet they occur more frequently, and in the mountains of British India they are very common, the hailstones being usually of large size. Hailstorms are not necessarily confined to the land areas, but may and frequently do occur over large and small bodies of water

THUNDER-STORMS.

These phenomena are atmospheric disturbances of great variability of extent and power. They are always accompanied by such manifestations of the presence of electricity as are ordinarily termed thunder and lightning, the former being

entirely consequent upon the existence of the latter. Thunder is but the reverberation of the concussion produced by the inconceivably rapid propulsion through the air of that physical element we are pleased to term electricity. Thunder-storms may be a few miles or several hundred in extent, and their length of duration is quite as uncertain, viz.: from a few hours to one or more days. There is no regular time of day for their occurrence, although they are perhaps more frequent in the afternoon. However, they may occur at any time during the day or night. As to the season of year, summer is the period of greatest prevalency. There is no month of the year entirely free from them. Whether the precipitation be rain or snow the presence of electricity has still been manifested in the usual form. With the former character of condensation of vapor the evidence of electricity is most common, while with the latter it is the rare exception. As regards geographical distribution, thunder-storms are most frequent between the equator and parallel 40° N., and from thence to parallel 70° N. the average frequency diminishes with considerable rapidity. In the vicinity of parallel 80° N. it is believed they never occur, although this in the main is mere supposition. There are certain portions of the United States where thunder-storms are unusually frequent as compared with other parts. They seldom appear in the Pacific Coast States, especially California, and are most frequent and violent in the Eastern Rocky Mountain Slope, the Lower Missouri Valley, and in the Lake Region.

Having briefly outlined the characteristics of the various classes of storms, we will now proceed to consider more in detail the most important (at least in certain respects) of all atmospheric disturbances. At this stage of our inquiry in regard to the character and classes of storms, I presume it will be admitted, that no two of the several storms defined, at least *appear* to be alike. There are, however, points of resemblance, but in some these features are stronger than in

others. As each is studied more carefully, the essential points of difference will be more clearly contrasted. It is not within the province of this book to discuss at length the points of difference or harmony, nor to enter into an intricate analysis of meteorological phenomena and the multiform operations of atmospheric changes attending the origin, development, and complete formation of these disturbances. On the contrary, it is simply desired to present a brief but comprehensive *résumé* of the leading features of storms, as known at least in the United States, if not in North America, and in particular to present rather a minute consideration of the peculiarities of tornadoes, with a view to place at the disposal of the *people most interested*, the facts and practical results of past and present investigations of this most terrible and yet most wonderful and interesting of storms, the dreaded tornado.

THE TORNADO.

What is a tornado? In defining this storm it would seem almost a necessity to rehearse its long line of striking characteristics, but this in the common acceptation of the term would not strictly be a definition. For the sake of brevity, we will state that the tornado is that form of atmospheric disturbance which takes the outward, visible fashion or figure of a funnel-shaped cloud, revolving about a vertical axis from right to left* with an inconceivably rapid movement and an immensity of power almost beyond calculation.

Conditions of Formation.—These may be divided into classes. First, those within the reach of and which may be known or investigated by an isolated observer. Second, those conditions only to be witnessed and analyzed by the intelligent and practiced eye of the student of the weather map. To the single observer, located mayhap at his farm home, the workshop, or the store, there are important atmospheric conditions which he may carefully watch and study with profit, viz.: the

* As you would turn a nut onto a bolt, point downward.

Near Fort Worth, Texas, June, 26, 1883. From an instantaneous photograph. Tornado-cloud passing fourteen miles away moving from S. S. W. Much property was destroyed, and three persons were killed in its track.

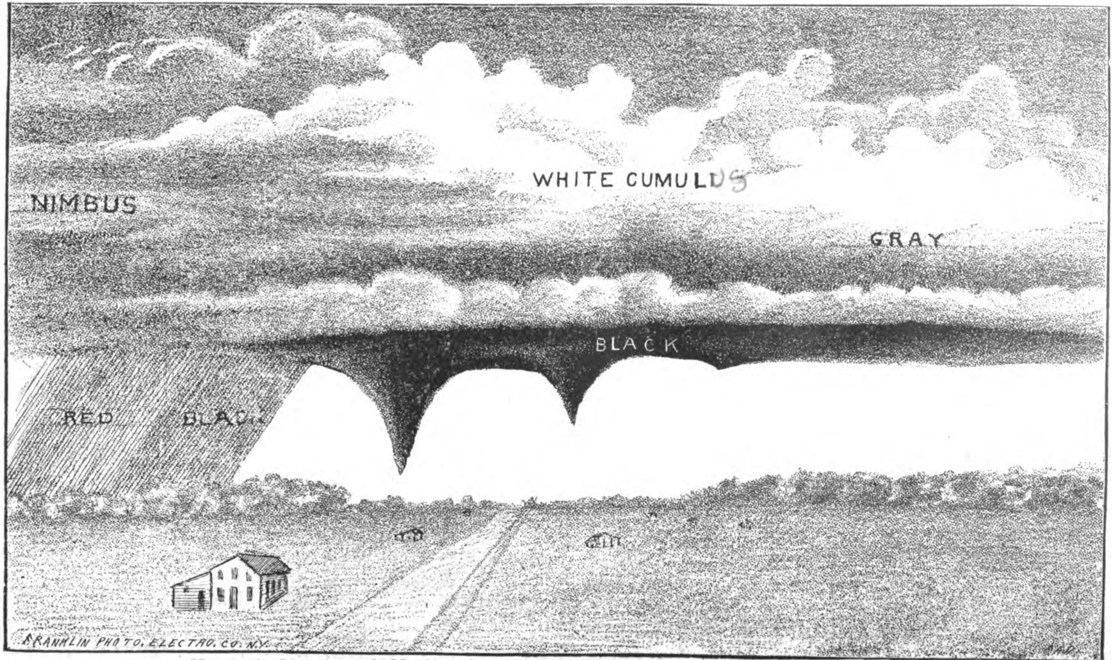
gradual setting in and prolonged movement of the air from the north and south points ; the gradual but continued *fall* of the thermometer with a prevalence of the northerly currents, or a *rise* with the predominance of the southerly. If the northerly currents are the prevailing air-movements at your place of observation, the atmospheric disturbance is forming to the southward, but if the prevailing air-currents are from the south the storm is forming to the northward of your location. Carefully study cloud development, color as well as form, also manner and direction of approach. The approach of the cirrus cloud (perhaps at a height of six to eight miles) from the southwest is very significant, and is the first evidence of the gradual but certain advance of the upper southwest current, which eventually plays so important a part in the development of the tornado-cloud. Clouds are but the embodiment of air-currents, yet they are full of meaning. A study of the upper currents of the atmosphere would be impossible without their manifestations, and that, too, in a variety of forms. Without cloud formation, the face of the sky would become a blank, and intelligent reasoning thereof a superhuman task.

Wind direction, temperature, and clouds are the proper subjects of observation and thought by the isolated observer. The barometer is of little if any importance in this line of inquiry. If you cannot compare your barometric observations with those taken at near or distant points and at the same moment of actual time, they are of no practical moment, even though your instrument is a standard one and your corrections for temperature and elevation carefully applied. The storm you are watching for (the tornado) is an extremely local affair, whereas the barometer indicates general changes,

NOTE.—Photographs of tornadoes and tornado-clouds are rare. We have the reproductions of three which are claimed to be instantaneous photographs, but the majority of our cloud illustrations are sketches from memory, most of them by persons not artists, and, while the collection is the most varied and perhaps the most correct ever published, we do not claim for it any higher merit than these facts will justify.

affecting a large extent of country. Your instrument, if a standard, does not lack possession of the delicate sensitiveness requisite for all the purposes of its construction, but if it were placed in the immediate track of the tornado-cloud, it would not indicate its presence until the crash of the storm was upon the instrument, when of course it would be too late. Barometrical observations appear to advantage and are absolutely necessary to a successful consideration of the meteorological conditions of tornadoes from the standpoint of the weather map. From this panoramic view of the situation a vast extent of country can be most carefully watched from hour to hour, for days, weeks, or months. Atmospheric conditions on opposite sides of the probable course of the storm can be watched from their inception, and any relation easily detected and analyzed. From a study of the weather-map it has been found that the formation of what is termed a barometric trough or elongated area of low pressure (where the barometer stands below the normal for that region at the hour of observation) precedes the occurrence of tornadoes in the Lower Missouri Valley or adjoining States to the south and east. This low-pressure area assumes the form of an ellipse and generally extends from southwest to northeast between northern Texas and the Upper Lake Region. Such a depression may lie between the Central Mississippi Valley and the Lower Lake Region, trending northeastward just south of Michigan and over the Ohio Valley. The major axis * of either of these depressions is easily estimated, while the minor axis may be stated as generally varying from three to five hundred miles. To the north of the major axis, even to a distance of several hundred miles, the winds are found to proceed from any or all points between northeast and northwest with comparatively low temperatures, accompanied sometimes by a cold rain or even snow. South of the major axis, and generally to a greater distance, the winds come from

* See chart No. 2, facing page 100; also illustrations on page 102.



Newtonia, Mo., Aug., 1882, about 6 p. m. From a rough pencil sketch made from memory.

any or all points between southeast and southwest, accompanied by comparatively high temperatures, high humidity, and often dashes of quite heavy rain.

As these conditions continue to prevail there is a growing contrast of temperature to the north and south of the major axis, owing to the long-continued movement of the atmosphere from opposite directions, such movement eventually affecting the disposition of air in the warmer regions of the extreme south and likewise the colder regions of the extreme north. The contrast of temperature now naturally increases with marked rapidity, and the formation of clouds commences in earnest. Huge masses of dark and portentous appearance bank up in the northwest and southwest with amazing rapidity, and soon the scene becomes one of awful grandeur. The struggle for mastery in the opposing currents is thus indicated by the gathering cloud formations. The condensation of vapor from the extremely humid southerly currents by contact with the augmenting cold of their struggling opponents continues. It increases rapidly. Finally, when resistance to the unstable equilibrium can no longer be maintained (controlled by the rate of temperature change and rapidity of condensation), the opposing forces are, as it were, broken asunder, followed by the upward rush of huge volumes of air. The outward indication of this event is first shown in the whirling, dashing clouds over the broken surface of the heavy bank of condensed vapor, forming the background. A scene not easily depicted or realized by one who has not witnessed it, but never to be effaced from the memory of the actual observer. There is an awful terror in the majesty of the power here represented, and in the unnatural movement of the clouds, which affects animals as well as human beings. The next stage in the further development of this atmospheric disturbance is the gradual descent of the funnel-shaped cloud from a point apparently just beneath the position of the enactment of the first scene. The tornado

is now before us, not fully developed, but soon to acquire that condition when the terrible violence of its power will make the earth tremble, animals terror-stricken, and men's hearts quake with fear.

PREMONITORY SIGNS.

On the day of the storm, and for several hours previous to the appearance of the tornado-cloud, the indications of its probable formation and approach are within the comprehension of any ordinary observer and can readily be detected by him. A sultry, oppressive condition of the atmosphere is thus described by various observers as follows: "I really experienced a sickly sensation under the influence of the sun's rays." "I was compelled to stop work on account of the peculiar exhaustion experienced from physical exertion." "It seemed as if the lightest garments that I could put on were a burden to me." "There was not a breath of air stirring." "The air at times came in puffs as from a heated furnace." "I felt a want of breath, the air frequently appearing too rarified to breathe freely." "I was startled at the sudden and continued rise in the thermometer, especially at this season of the year." "In the forenoon I actually wore an overcoat, but shortly after dinner I put on my straw hat and worked in my shirt sleeves." "I noticed a remarkable change in the temperature, many of the neighbors spoke about it and said that there was a peculiar feeling about the heat, something they had not before experienced in years." "It was terribly oppressive; it seemed as if the atmosphere was unusually heavy and pressing down on me with a great weight."

These citations clearly indicate the character of this peculiar sultriness. Other signs equally important and reliable may be found in the development and peculiar formation of the clouds in the western horizon. Sometimes these peculiar clouds extend from the southwest through the west

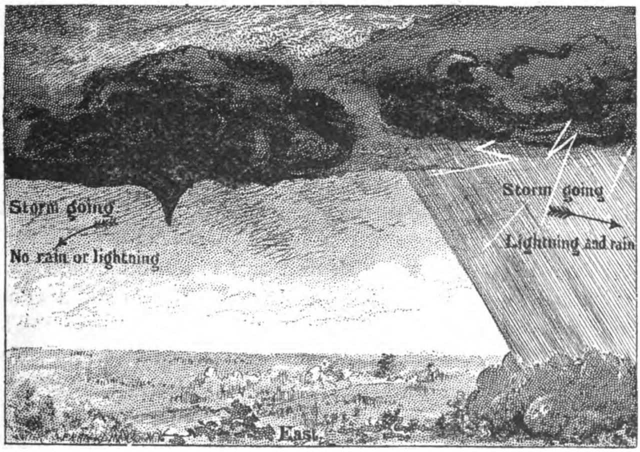
by the north to the northeast. More frequently, however, they form in the northwest and southwest, sometimes commencing, first in the former quarter and then again in the latter, but in either case they are equally significant. The marked peculiarity of the clouds is found to occur not only in the *form* but in the *color* and *character* of development.

The sudden appearance of ominous clouds, first in the southwest and then almost immediately in the northwest or northeast (perhaps the reverse in the order of their appearance), generally attracts the attention of the most casual observer, and frequently overcomes him with astonishment. In almost all cases these premonitory clouds are unlike any ordinary and usual formation. If they are light, their appearance resembles smoke issuing from a burning building or straw-stack, rolling upward in fantastic shapes to great heights. Again, like a fine mist or quite white, like fog or steam. Some persons describe these light clouds as at times apparently irridescent or glowing as if from their irregular surfaces a pale, whitish light was cast.

The dark clouds at times present a deep, greenish hue, which forebodes the greatest evil and leaves one to imagine quite freely of dire possibilities. Again, they appear jet black from center to circumference, or, in a change of form, this deep-set color may only appear at the center, gradually diminishing in intensity as the outer edges of the cloud or bank of clouds are approached. Sometimes these dark clouds, instead

NOTE.—The following three pictures are of the great tornado at Ercildoun, Chester County, Penn., July 1, 1877, and are from very rough and imperfect sketches. The storm formed about 2:30 P. M. and passed in a direction nearly due east for about twenty miles, injuring many people and destroying over $40,000 of property. Width of track, 150 to 300 feet. Diameter of tornado-cloud, 50 to 75 feet. It is described as having very closely resembled a balloon, although the sketches do not disclose that fact. A balloon-shaped cloud is represented on another page as having appeared near North Vernon, Ind., in 1883.

of appearing in solid and heavy masses, roll up lightly, but still intensely black, like the smoke from an engine or locomotive burning soft coal. They have been described as of a purple or bluish tinge, or at times possessed of a strange lividness. Frequently dark green, again an inky blackness that fairly startles you with its intensity. Many observers are at a loss for words in which to give an adequate description of the terrible scenes and simply say : "They were the worst-looking clouds I ever saw, perfectly awful." Said one observer, "The clouds seemed to be boiling up like muddy

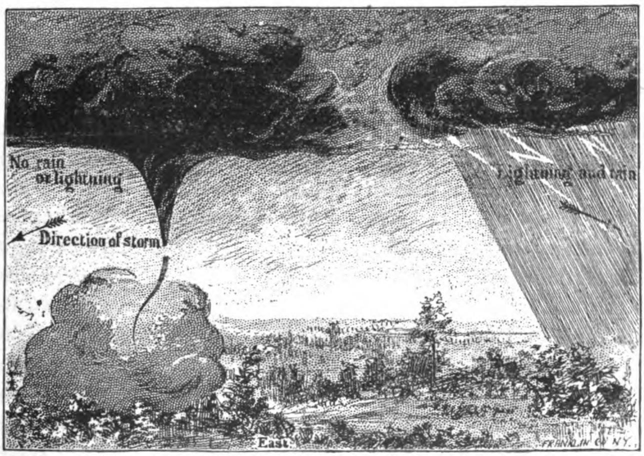


Tornado at Ercildoun, Pa., July 1, 1877. First appearance. See note on page 26 for description.

water, the upper surface of the cloud reminding me of the incessant eddies or whirls seen in the muddiest portions of the Missouri River." Other observers as follows : "I saw two whirling circles of lightish gray clouds in the west ; they were acting independently of each other and moved slowly inward toward each other from opposite directions. The clouds were very low, seemed to be on the earth, the wind

in contrary directions across the face of the western sky and surrounding clouds in great confusion." "Observed clouds moving in all directions, some of a dark green color, others white as steam." "The lower end of the cloud was very white, like fog." "I saw a great smoke, and supposed at first it was a fire." "I saw a terrible cloud of a dark purplish color." "There was a peculiar and terrifying look to the clouds." "I saw a green-looking cloud in the northwest, surrounded by others not so deep-set in color. Under the cloud from the southwest, there came a large number of little thunder-heads, some very dark but others as white as steam. They seemed to be separated and running very low. I never saw clouds so low before. Pretty soon they began to go in all directions, some up, some down, right and left, backwards and forwards. I next saw a cloud that looked even all over in color and very white, the edges pretty even. It moved remarkably steady and seemed to be right under the edge of the cloud from the southwest." "The clouds looked as if a mosquito-net had been spread out over the sky." "I saw clouds tumbling over and over in terrible confusion." "I noticed a strange action in the clouds and saw a cloud rolling on the ground coming from the southwest." "The ground was covered with white, steamy-looking clouds that prevented one from seeing any distance." "Two clouds, one from the northwest and the other from the southwest seemed to meet, and after meeting passed still lower. Above their place of meeting black smoke appeared in very peculiar shape." "The air presented a very peculiar appearance, it seemed to be in different-shaded strata and quite marked." "At the bottom of the cloud a hazy appearance rose up, obstructing the view." "Two clouds came together, one from the southwest and the other from the northwest; the latter was the highest, and the former the heaviest and looked the worst." "A heavy cloud spread out before us to a width of about six hundred feet, and as black as night."

The peculiar *action* of the clouds while they are forming is another interesting and significant feature which should be carefully watched. Under ordinary circumstances clouds form, move about, and disappear without causing the slightest remark, or perhaps thought, from the casual or even the interested observer. In the event of a thunder-storm or hail-storm the movement and disposition of the clouds are not looked upon with fear or as possessed of power to create great havoc, but on the occasion of a tornado the formation and movement of the clouds strike most persons almost



Tornado at Ercildoun, Pa., July 1, 1877. Later appearance. See note on page 26 for description.

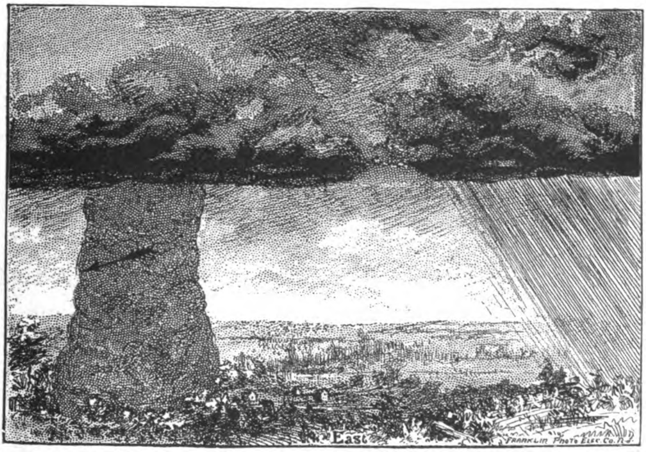
dumb with fear; there seems to be some strange connection between the almost simultaneous appearance of clouds in the southwest and northwest, possessing as they do such unusually threatening forms.

As they approach from opposite directions they are suddenly thrown into the greatest confusion; breaking up, as it were, into small portions, which dash pell-mell over each other and in every direction; now darting toward the earth,

now rushing upward to considerable heights like sky-rockets, or at moderate elevations rolling over each other in a well-developed whirl. An observer, in describing the approach of the clouds from the southwest and northwest, stated that they "came together with a terrific crash, as if thrown from the mouths of cannons." Generally, following closely upon the existence of this condition, the funnel-shaped tornado-cloud appears against the western sky, moving boldly to the front from without this confused mass of flying clouds. As the tornado-cloud advances these scuds continue to play about its top and sides, constituting a characteristic feature of the scene.

Another and invariable sign of the tornado's approach is a heavy, roaring noise, which augments in intensity as the tornado-cloud advances. . This roaring is compared to the passage of a heavily loaded freight train moving over a bridge or through a deep pass or tunnel. To the roaring of a railroad train such as is heard on damp mornings when the sound is very clear and loud. The sound coming from the rapid movement of a large number of empty box cars is accounted rather peculiar and quite noticeable. At times the roaring has been so violent that persons have compared it to the simultaneous "rush of 10,000 trains of cars." Of course, there is no importance to be attached to the exact *number* here given, it being used in a figurative sense and is quite likely exaggerated. Again, the roaring is likened to the low rumbling of distant thunder. The varying intensity of the roar as here represented is, in the main, due to the lack of uniformity in the positions of the various observers with respect to the advancing tornado-cloud. Those situated nearest the cloud, other things being equal, experience the loudest roar, while to those at greater distances the noise is proportionally weaker. In any event, however, the noise is sufficiently peculiar and distinct to create alarm, and as a means of *warning* should not be overlooked under any pretext.

How to Benefit by Signs.—In order to be prepared for the possible appearance of a tornado, so far at least as the above indications are concerned, let every person situated in those regions of country where the tornado is of yearly occurrence commence (to-day is none too soon) to carefully observe and record the daily changes in the face of the sky, the variations of temperature, the direction of the wind and



Tornado at Ercildoun, Pa., July, 1, 1877. Last appearance. See note on page 26 for description.

the character and development of clouds. We do not mean that any person should devote all or most of his time to this work of observation, and possibly not even all of his spare time. For the sake of regularity and uniformity we will suggest certain hours for regular work of this nature, viz.: 7 A. M. and 2 and 9 P. M. These hours are not altogether arbitrary, but there is a reasonable amount of prudence in their selection, looking to a proper and successful use of the results of your labor.

Should the violence of a storm be unusually marked during either the hours of the forenoon or afternoon, or even in the

night, it would be advisable to increase the number of hours for observation and record, possibly making them every hour or half hour, or even at shorter intervals, as the importance of the case demands. By this means of frequent observation every feature of the storm would become the subject of inquiry and the most important results would be attained. For purposes of investigation of this class of storms your observations need not continue throughout the entire year, at least in the Northern and Western States, although such a length of record would by no means fall amiss of great value. Yearly records will pay. However, observations should commence without fail by the 1st of April, and continue unremittingly until at least the last of September. Observations through the autumn can be maintained with profit. It will be a valuable adjunct to this work of regular-hour records if a summary of miscellaneous phenomena is kept Enter the dates of occurrence and important particulars of such phenomena as auroras, mirage, meteors, lunar and solar halos, prairie and forest fires; the migration of birds and insects; the leafing and blossoming of trees, flowers, and shrubs; droughts, excessive rainfalls, earthquakes, zodiacal light, frosts and the formation of ice. The great importance of systematic observation and record is urged with much earnestness, particularly in the tornado districts and during the tornado season, but further detail is omitted in this place and the student and volunteer observer are warmly recommended to examine the tornado circular of the Signal Service, which is printed in full at the end of the book. It contains 234 questions and suggestions, under eighteen different headings, and constitutes the most complete, as well as the most compact, scheme of instruction ever compiled for the purpose.

Character of Tornado-Cloud and Attending Motions.— The tornado-cloud is, generally speaking, funnel-shaped, that is to say, it tapers from the top downward, not always

in the same degree with every appearance of the cloud, but the lower end of it (the part nearest the earth) is invariably the smallest. Whatever the inclination of the central axis of the cloud to the vertical or plumb line, the lowest end is the narrowest and nearest the earth. As seen in different positions and stages of development by various observers, located differently, the tornado-cloud has been called: "balloon-shaped;" "basket-shaped;" "egg-shaped;" "trailing on the ground like the tail of an enormous kite;" of "bulbous form;" "like an elephant's trunk," etc., etc. In the majority of instances, however, observers describe the cloud as appearing like an upright funnel. When the tip end of

Tornado-cloud which passed near Garnett, Kansas, at 5:30 P. M. April 26, 1884. From an instantaneous photograph.

the cloud reaches the earth, the violence of its whirl creates a powerful suction over a small portion of the surface, upon which there is immediately formed a peculiar cloud of dust, and finely divided débris, around which play small gatherings of condensed vapor. To all appearances now, the tornado-cloud has two heads, one on the surface of the earth and the other in the sky, the bodies of each joining in mid-air and tapering both ways with the smallest diameter at their junction. In other words, the cloud now assumes the shape of an hour-glass and the lower portion, or that assuming the form of an inverted funnel, displays an extraordinary violence. The extreme fury and the tremendous power of the tornado-cloud are now experienced, and nothing is able to stay the awful force of its onward march. This last and most fatal form of the tornado-cloud is fortunately not a constant feature of the storm. The tornado-cloud is constantly changing from the hour-glass form to that of the upright funnel or some other intermediate shape previously referred to.

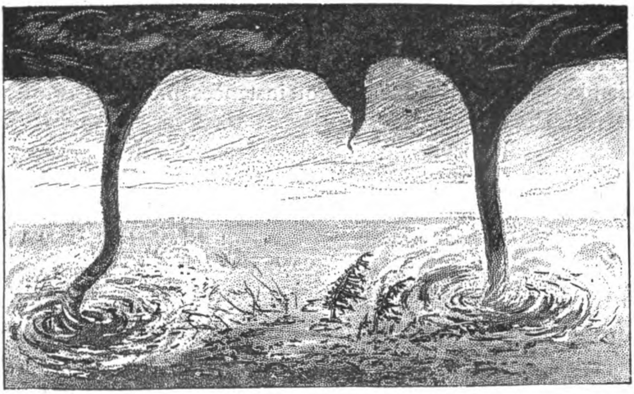
The various gradations of form, not any of which, however, affect the stereotyped relation between the size of top and bottom, number some twenty-five or thirty, so far as I have been able to gather information upon this point. These variations of form are quite important in a critical study of the tornado. They depend upon the peculiar movements of the whirling currents of air within and about the cloud vortex, the direction of the currents being outlined to the eye by the singular disposition of the rapidly condensing masses of vapor. The characteristic motions of the tornado-cloud number four, and are described as follows:—

No. I. is called the *whirling* or *gyratory* motion of the tornado-cloud, which is invariably from right to left, or against the course of the sun. From the peculiar character of the formation of the tornado-cloud, this motion is in all probability the first evidence of the existence of the cloud, and

should therefore be placed first in order of consideration. Above all other motions, this is attended with the greatest violence, and its velocity of movement is far in excess of any of the others. This gyratory motion forms what is termed the vortex of the tornado-cloud, within which the velocity of the centripetal currents of air is almost beyond conception. Many efforts have been made, but most of them altogether fruitless, to estimate the rate of progress of these currents, and velocities ranging from 100 to 800, and even 1,000 miles per hour, have been deduced; the two latter are the extremes that have been ventured upon and of course are not reliable, while in the majority of instances more trustworthy determinations have ranged between 100 and 500 miles per hour. Theoretical velocities of over 2,000 miles per hour, based upon certain assumed atmospheric conditions, have been deduced. Such velocities are mathematically possible, but not meteorologically probable.

The uncertainty in computing the velocity of centripetal currents arises from the difficulty attending the acquirement of the requisite data. In all carefully conducted investigations heretofore made, there has unfortunately occurred such a long interval between the happening of the storm and the arrival of the person authorized to commence the work, that valuable and satisfactory results in this direction were precluded. It is always of prime importance to ascertain definitely what portion of a building or other object was first struck by the wind in order to determine the configuration and inclination of the exposed surface. As a rule such examination is rendered next to impossible by the rapidity with which devastated districts recover from the violence of the storm. This fact is a most praiseworthy and well-deserved commentary on the exemplary industry and determined spirit of the people of the Lower Missouri Valley. With the gyratory motion of the tornado-cloud, objects are drawn inward to the center of the storm and then carried

violently upward, by a spirally inward and upward motion which fairly crushes and grinds into pieces buildings, trees, and whatever else falls in the line of the advancing cloud. The spirally upward motion throws the ascending débris in a circular manner outward at the top of the tornado-cloud. This débris, when beyond the central whirl of the cloud, falls to the earth, but in such a manner and so disposed as to indicate the character of the force which acted upon it.

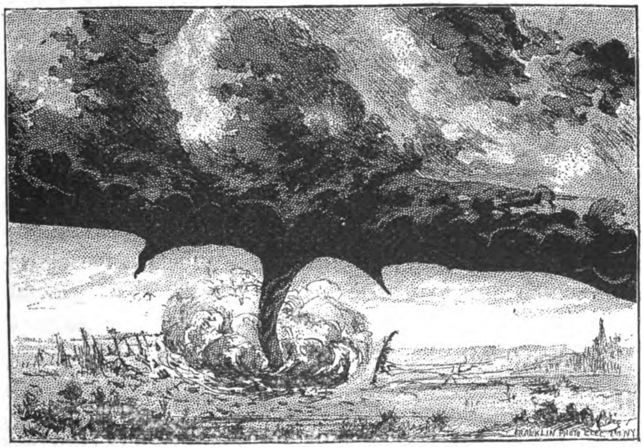


Tornado near Redstone, Davison Co., Dakota, Aug. 28, 1884. From a sketch by J. H. Nott. See opposite page. These two pictures of the same storm, made 20 miles apart in adjoining counties by different persons having no knowledge of each other, are valuable confirmations of one another.

No. II. is called the *progressive* motion of the tornado-cloud, the motion which determines the cloud's track from one point to another. The rate of progressive velocity ranks next in order to the velocity of motion No. I., although it is at all times far below the high degree of the latter.

The rate of progress of the tornado-cloud is subject to great variability throughout the path of any one storm, although on the average tornado-clouds possess a moderately uniform velocity of progression. Some observers have indicated the movement by the following expressions: "All in an instant." "Gone in a moment." "Quicker than

thought." "Without a moment's warning." "It moved no faster than a horse gently galloping." "I just saw what it was and then all was over." "Before I had time to turn about in my tracks it flashed by me." "It seemed to remain almost motionless, as if held to the ground by some mysterious force." "I shuddered, held my breath, and the monster had vanished." "It seemed to move no faster than I could run."



Tornado-cloud as seen at Howard, Miner Co., Dakota, Aug. 28, 1884. Photographed by F. N. Robinson. The cloud passed 22 miles west of him in a south-easterly direction, remaining in sight over two hours. Several people were killed, and all property in the path was destroyed.

These estimations of velocity are not to be taken altogether literally. The circumstances under which the impressions were received must be considered, viz.: undue excitement or abject terror. However, the comparative results are important, and to a certain extent reliable. Through them, the reader will at least not be led astray in his conceptions of the awful grandeur of the panorama, or fall into the fatal mistake of encouraging a belief that the tornado is not what the united experience of all observers has portrayed it.

Such data will not answer, however, to figure on very closely, but the items, average diameter of cloud, actual time (local or standard), and measured distances, must be carefully obtained before an approach to accurate calculations can be secured. Reliable data are very difficult to obtain, especially time. This fact should be thoroughly appreciated by observers and every reasonable effort made by them to examine their clocks or watches upon the approach and passage of the tornado-cloud. Generally speaking, it is a good habit to form, of jotting down in some place of ready reference the hour, day, month, and year of notable events. In regard to this matter of time, so far as past determinations can be valued, the progressive velocity of the tornado-cloud is variously estimated at from twenty-five to seventy miles per hour. The former is perhaps too low and the latter quite likely too high, and although in both instances they represent the extremes, yet either of the above velocities may have existed for short intervals. The general average is probably about forty miles per hour.

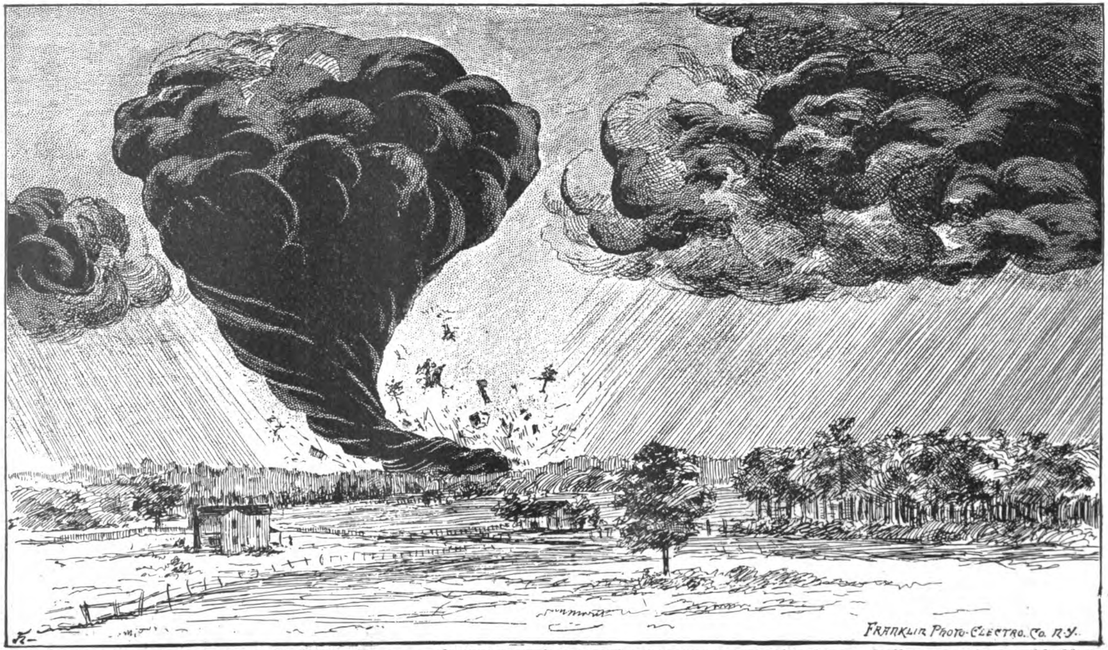
No. III. is termed the *rising* and *falling* motion of the tornado-cloud, the character of which finds definition in the following expressions from various witnesses: "The top of the cloud seemed to pop up and down, and then to rush forward." "It bounded over the ground like a ball." "It was the strangest jumping and flopping object I ever saw." "At times it seemed to lash the earth in terrific fury with its huge tail." "It came along, popping up and down in a most fantastic way." "Rising up like the uncoiling of a huge rope, it cut loose from the earth and passed over us with a horribly whizzing sound." "Ever and anon it would shoot directly upward from the earth, sometimes with great rapidity, and then again quite slowly, each time dashing to the surface with apparently renewed vigor." It is perhaps clearly seen that this is a distinct motion with striking peculiarities which define its character. Sometimes, upon the

lifting of the tornado-cloud from the earth, it does not again descend for a distance of several miles, at times making the return movement or descension twenty or thirty miles distant, the intervening space proving a complete blank in its track. More frequently, however, these gaps are from one to five miles in length.

While the tornado-cloud is traversing the atmosphere at some considerable distance above the earth, it may reach down so low as to just skim over the tops of the highest trees; descend to a level with the roofs of buildings, simply scaling off the shingles in spots or entirely on one side, leaving the roof-boards and rafters unmoved; removing the tops of chimneys; taking out all the fans in the wheel of a windmill and leaving every portion (even the tail) of the remainder of the mill unharmed; take off the cornice without disturbing the remainder of the roof; removing simply the top board of a five-board fence, or one or two of the top rails of an ordinary rail fence. The tornado-cloud may, however, remain at a perfectly safe distance throughout its aerial course, and where it may be seen at a great height, moving solitary and alone, like a huge balloon. While in this condition it has not a few times been unwittingly taken for the latter object, but the mystery and sensation were entirely dispelled when the news came in from the surrounding country of the frightful power of this now silent monster.

There is still another condition, which the fearful aeronaut may assume in his flighty movements. Upon rising from the earth and passing through a few uncertain struggles, apparently to decide as to whether the final direction shall be up or down, the tornado-cloud is ultimately lost sight of in the surrounding clouds, and re-appears suddenly again at its point of descension, or perhaps only to remain at a safe distance.

No. IV. is called the *zigzag* motion, or swaying from side to side of the central line of cloud movement. This motion



Near North Vernon, Ind., June 10, 1883. From a rude pen sketch, made from memory after the storm. Balloon cloud passed half a mile from the town.

is sometimes quite suddenly performed, but generally it is a moderately slow movement and one that can be watched and easily identified. It seems to occur most frequently just as the tornado-cloud touches the earth in completing the last act of motion No. III. In completing the extent of a single act of this motion, the tornado-cloud will diverge about an equal distance on either side of the central line of movement, though these tangents to the major axis are not necessarily of equal length.

At the commencement of this motion the tornado-cloud always moves first to the left (N. N. E.) and then to the right (E. S. E.) forming an obtuse angle on the north side of the major axis. On the return movement, the cloud may or may not cross the major axis (to E. S. E.). If it does, it will then form a similar obtuse angle on the south side of the major axis. This zigzag movement, first from one side and then from the other of the central line of progressive action, may continue for several miles, or it may cut short its existence after the first few moves. The regularity of this peculiar action appears to depend upon indraughts from the south side of the major axis of violent currents of air, which frequently advance (only from the south side) and give evidence of their existence by swaths or narrow paths of destruction (alternating with spaces of no damage) cut inward toward and joining with the central line or track. The tornado-cloud may, upon the return movement (whether executed upon the north or south side of the major axis, it matters not), fail to cross it, but upon reaching it, continue onward in the central line of movement to the northeast.

The distance traveled by the tornado-cloud in departing from the major axis, either to the north or south, is generally subject to considerable variability, ranging from forty or fifty yards to nearly as many rods. While executing this zigzag motion it very frequently happens that the tornado-cloud simply skims over the earth without manifesting its extreme violence.

Building Spots.—In regard to the matter of buildings, the question may be asked whether there is not some choice in a building spot, with a view to safety from the violence of the tornado-cloud. Many persons have thought that if their house or barn was perched upon some high "divide," or on the brow of a steep decline, in fact upon any marked rise above the surrounding level, the tornado-cloud by reason of some mysterious effort of clemency would rise from the earth and pass over them. This is a careless and unreasonable supposition when the facts are known. It does not seem to occur to the mind of an observer that there is no reason why the tornado-cloud should not follow the rolling surface as well as the plain. The tornado-cloud pursues a general course to the northeast without regard to the character of the earth's surface, and if your buildings are in the line of its destructive path, whether upon a hill, in a valley, or within a ravine, they are subject to its violence. Western towns as a rule are not built upon high "divides," but are more frequently sheltered between neighboring hills. The same may be said of farm buildings, it being the prevailing custom to select building spots along the low bottoms of a stream for convenience to water and timber, and for protection from the continued heavy winds that break over the open prairies.

From the above facts it will be seen that there is very little opportunity offered the tornado-cloud to display its violence on the hill-tops, even though it were so disposed. Repeated investigations have shown that buildings were destroyed with as great violence and completeness upon high lands as upon low lands, but the largest number in valleys because of the facts above cited. In many instances the funnel-cloud has passed from one ridge to another, doing damage on both, but skipping the intervening depression. Again, it has followed high "divides" for several miles where they coincided with its general course of movement. Ridges and valleys

are almost invariably crossed at right angles when their courses are from northwest to southeast.

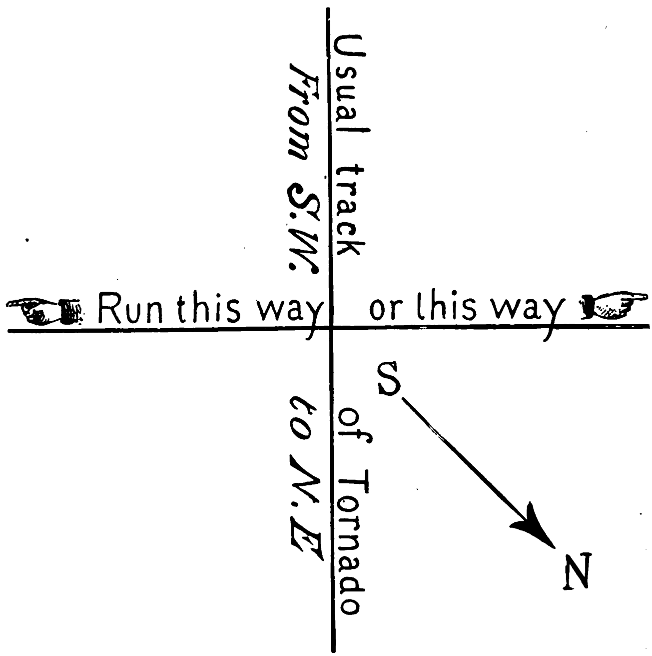
Electricity.—The rain and hail which sometimes precede and at other times follow the tornado-cloud, but always accompany the heavy clouds which form in the north and west, are not always but generally attended by lightning; sometimes most violent manifestations, and then again but occasional flashes. The most terrific displays are reported during the heavy precipitation which often occurs after the tornado-cloud has passed, some ten to twenty minutes. Very often its darting flash is observed in the dark clouds which begin to rise above the western horizon an hour or more before the storm. The relations of electricity to the tornado are so fully and so conclusively set forth in the "Scientific Résumé," printed at pages 147, etc., that further examination of that particular point is omitted here.

PROTECTION.

If you have a tornado-cave or a dug-out, get into it with your family and your treasures before the storm reaches you; if you have no such means of retreat and cannot get away from the storm, go into your cellar and get as close to the west wall as possible, *never go to the east side* of a cellar or of any other inclosed space in any building toward which the tornado is approaching; ALWAYS SEEK THE WEST SIDE, TOWARDS THE STORM. Frequently life may be saved by timely flight *in the right direction.* A tornado travels from southwest to northeast; stand facing it as it approaches; if it is going to the right of you, run to the left; if it is going to the left of you, run to the right; *never run towards the storm nor with it,* ALWAYS RUN TO THE NORTHWARD OR SOUTHWARD AT A RIGHT ANGLE FROM IT, GIVING THE BENEFIT OF DOUBT IN FAVOR OF THE NORTH. Read attentively the small print following for details in regard to saving life, property, and live-stock.

MEANS OF PROTECTION.—First in regard to life. How can you save your life or avoid injury? In regard to this question much, if not everything, depends upon the manner and in what direction you *move*, together with the distance of the tornado-cloud, its direction, and the kind of motion prevailing at the instant you determine upon changing your location.

We will now suppose the various conditions, and proceed to point out the necessary action in each instance. In all cases it is granted for the sake of convenience in illustration, that you are in front of or situated directly in the line of the advancing tornado-cloud. Under these circumstances if No. II., or the progressive motion of the cloud is prevailing,



and your distance from it is, say, eighty rods or more, move directly and with all possible dispatch to the north. Whenever this motion is prevailing always run to the north, unless in so doing you would be obliged to cross the entire path of the storm. A sharp glance to the

westward will tell you whether you are about on the southern edge of the probable path of the tornado-cloud, or more to the north. If in the center or half-way between the center and the southern edge, your chances are best in a direct course to the north. If further to the south, move directly and very rapidly to the south, bearing slightly east. In no event should you ever run directly to the east or northeast. Suppose the tornado-cloud to be distant from you (W. or S.W.) eighty rods and its progressive velocity sixty miles per hour, it would follow that one mile is passed in sixty seconds, or eighty rods in fifteen seconds. Assuming the average width of the destructive path of the tornado-cloud to be forty rods and your position at the center of that path, it will be seen that you have fifteen seconds in which to reach the outer edge of the path to the *north* (a distance of twenty rods) before the tornado-cloud could arrive at your location.

I have taken an extreme case in every particular. Most persons first see the tornado-cloud at a much greater distance, from one to three miles, sometimes five and ten miles on the prairies. Of course, at the unusual distance of five or ten miles you could not determine very satisfactorily its probable course, especially with regard to your buildings or the safety of your own location. Watching the approach of the tornado-cloud closely at a distance of ten miles, and from that position on and on in its eastward course until it came within a mile or so of your point of observation, would give you sufficient opportunity to predict its probable course in regard to your location. When that matter is settled satisfactorily to your judgment, move immediately and without further hesitation. If you wait until the tornado-cloud is distant one mile, you have at least sixty seconds in which to run a distance of thirty rods, supposing that you are obliged to cover more than half of the destructive path of the storm. In an average case you will probably have between eighty and ninety seconds in which to run a distance of twenty rods. In either case I am supposing that you are prepared in every particular to move at the very instant of timely warning. Further, I am supposing that you have been watching the weather of the day and understand that a terrible storm is imminent. There is, under ordinary circumstances, no reason why you should not be so informed. A tornado-cloud does not come out of a clear sky, and there are many and ample signs of its approach.

What has been said in regard to the directions in which persons should move when the progressive motion is prevailing, will for all practical purposes apply to motions Nos. I. and III. With respect to motion No. IV. (the zigzag) the following preliminary remarks should be most carefully considered. Remember that while possessed of this

motion the tornado-cloud crosses from one side of the central line of movement or major axis to the other. That this peculiar motion most frequently occurs just after the termination of the rising and falling motion (No. III.), so that when you see the tornado-cloud descending to the earth from one of its aerial flights you may expect (not absolutely) the zigzag motion to follow. That the first departure of the tornado-cloud from the major axis is to the left or on the north side of the path. That all departures from the major axis, whether forward or return movements of the tornado-cloud, are invariably executed to the eastward. There is no backward movement to the west. That the tornado-cloud never continues to move in the direction of any tangent to the major axis, but in the event of any departure it ultimately returns to the central line of movement. Having these points well in mind, you are quite satisfactorily prepared to act when the exigency occurs. When the departure of the tornado-cloud is to the left and your position is at any point in the central line of movement (better near the center of the path), move directly north with the utmost rapidity, even if the cloud is at a long distance from you. Should it chance that your distance from the cloud is reduced to from twenty to forty rods, run instantly to the south, bearing slightly west. This movement will take you away from the forward and return action of the tornado-cloud. Another case, suppose your position to be the same as just given, viz.: at any point in the central line of movement, but that the tornado-cloud had just crossed over that line to the southward. In this event you should move instantly and directly to the north, bearing slightly west. This movement will also, as in the case previously cited, take you away from the forward and return action of the tornado-cloud.

How to Act on its Formation.—The following remarks apply to your manner of action when the evidences of the existence of the tornado-cloud are undeniable. Suppose the actual tornado cloud is not yet in sight, but other infallible signs (heretofore given) of its formation and probable approach from a point possibly below your horizon, are present. Act immediately, judiciously, and with the utmost rapidity, but never for one instant allow yourself to become excited or reckless in anything. Take the situation as calmly as possible, knowing as you ought (or probably will) the terrible power you have to deal with. Do not, with an overweening sense of fancied security or an inclination to a superstitious feeling that your life is mysteriously over-shadowed by a peculiarly beneficent power, think and act leisurely about the matter of self-protection. A tornado-cloud never sends forward a flag of truce or even solicits the "right of way." There are certain indications which we have heretofore spoken of that frequently, if not always,

manifest themselves from half an hour to two or three hours in advance of the tornado-cloud.

Many foolhardy acts have been committed, perhaps through fear and excitement or positive ignorance, which have resulted in death or dreadful injuries, because persons have tried to run in front of the tornado-cloud, thinking they could outstrip it in such a race. Others have attempted to cross the path just ahead of the advancing cloud, feeling that they could reach a safe distance on the opposite side before the funnel-shaped monster passed. In one of our late storms a person essayed this trip with two horses and a lumber wagon, confident that he could at least rush his horses across the apparently narrow path of a storm which seemed to progress within such circumscribed limits. Not so. He was instantly killed, one of his horses dreadfully mangled, the other seriously injured, and the wagon a total wreck. The work of an instant. An ignorant, reckless rush into eternity.

PROTECTION OF PROPERTY.—What can be done to in any way lessen the actual damage (present or prospective) to property, especially buildings? In the first place it is impossible to move your buildings from the path of the advancing tornado-cloud. Secondly, it is impossible to stop the tornado-cloud after it has started on its course of death and destruction, or in any way prevent its formation. Thirdly, it is impossible to construct any building strong enough to completely resist the extraordinary violence of the tornado-cloud. To sum up, this is all equivalent to saying that you can never expect to save your buildings. This is the truth as I comprehend it, and it is that to which all thought upon the subject will sooner or later conform. It is advisable that, under all circumstances, you should avoid any labor especially directed to the construction of any building whatsoever, for the express purpose of resisting the violence of the tornado-cloud. Build your houses, barns, and stores as you would without the knowledge of a tornado. Other things being equal, a frame building is better than a brick or stone one. The former will hold together longer, is more elastic (if you will permit the term), and persons seeking refuge within its walls are much less liable to injury. There has at times been evidence to show that, of all frame buildings, those constructed with a hip-roof and a story and a half in height were the best able to resist the violence of the tornado. But where there are cases reported of this class of buildings being saved there are as many, if not more, where they were destroyed precisely as any other frame building would have been under similar circumstances.

It matters not how you construct or of what material, if your building rises above the surface of the earth, which it must necessarily do, it

thereby offers obstruction to the advance of the tornado-cloud, and it will go, either from the foundation, or into kindling-wood and a distracted mass of bricks and mortar, in spite of the propagation of any theory on the possibilities of architectural skill. In conclusion I would finally say, that you must take every precaution to avoid or remove from, rather than attempt to fight against or any way resist, the power of this formidable adversary. The question now suggests itself, what can be done? That which remains to be done can be accomplished in an unostentatious and quiet, but secure manner. Every man can and should construct a tornado-cave at some suitable point, within a convenient distance of his house. If a person is situated within a town or city, let him select some portion of his yard for the purpose, but if residing in the country he will not be confined to narrow limits in the selection of a desirable location. Where a person living in the village has no yard, he must, if he has a cellar, construct a cellar tornado-cave to be described further on. With respect to the tornado-cave, in no event should the roof be other than level with the surface of the earth; in fact it is highly desirable that the retreat should be so constructed that the ordinary surface of the earth would form the roof or covering, and that all preparation of the domicile proceed by way of excavations and supports from beneath. As to location, the most important points are, excavation of cave to the westward of house or other building; convenient distance; a high, dry place, and possible opportunities to excavate into the northern or eastern slope of a knoll or hill. In the latter instance the entrance way would suffer less from the violence of the storm, providing, perhaps, that it did not entirely envelop your retreat, for in that event, in the whirl of the flying débris, all sides alike would be at the mercy of the winds. Having decided upon the location, as regards your house or other buildings, sink a shaft, say, four to six feet square, the entire depth of your tornado-cave. From either the northern or eastern (better the former) wall of this shaft, make the necessary preparations for purposes of ingress and egress. On the west side of the shaft commence the excavation for the inclosed retreat. The size of the room will of course depend upon how much you may at any time wish to secure from injury. Better have the excavation too large than not large enough. The slight difference in the expense of time and labor may, perhaps, be the means of saving you a great deal when you least expect it. The entire room should be below the surface of the ground a distance of at least three feet, and the overhanging roof of earth should be supported from beneath by heavy timbers, to provide against any emergency, like the dashing of heavy débris upon it or the tramping of horses and cattle.

In the event of a tornado your retreat (tornado-cave) may be entirely buried beneath huge piles of débris. Everything must be made as secure as possible. The entrance door should be made, either of sheet iron or of the heaviest timbers and supported between casings of similar strength of construction. Arrangements should be made to secure the door by heavy fastenings. In order that ventilation may be provided for, a box spout, of hard wood or vitrified tile, squaring about eight inches, can be let through the roof. The top of this spout must be level with the surface of the ground and protected by iron gratings. Ventilation may be provided for by openings through the upper portion of the door, but these also should be protected by iron gratings. The question of how to provide the most approved form of tornado-cave, with every detail of cost, material, and method of construction, is very fully considered a few pages further along.

If you are not possessed of the tornado-cave or cellar tornado-cave, your best plan is to move from your house or wherever you may be at the moment, as directed concerning the various motions of the tornado-cloud. If not able to benefit by these directions, retreat instantly to your cellar and place yourself, face forward, against the west wall. This is the best position in any cellar. If, for any reason, you cannot get to the west wall, take your position (the next best) face forward against the south wall, but as near the southwest corner as possible. In these positions the building, if removed from the foundation, will always be carried above and over you, or if torn to pieces, the débris will be instantly removed to the eastward. *Under no circumstances, whether in a building or a cellar, ever take a position in a northeast room, in a northeast corner, in an east room, or against an east wall.* Remember that the tornado-cloud invariably moves in a northeasterly direction. I have not space here in which to relate to you, how many and in what manner, persons have been instantly killed or terribly crippled, for no other reason than that they ignorantly threw themselves within the very grasp of the monster cloud. The lives of most, if not all, of the people destroyed in tornadoes might have been saved by a clear understanding and a strict adherence to the simple rules herein set forth.

The rule prohibiting movement to the northeast must be obeyed. The northeast quarter is a fatal position, and I care not what you may tell me about destruction to life or property in any other. If you can get out of your house never remain in it or any other building that is at all likely to be torn down or removed from its foundation. If through some misfortune you are closely pressed by the advancing cloud, never remain standing and attempt to weather the storm, but throw yourself prone (face downward) upon the ground, head to the

east, and arms thrown over the head to protect it. If you should chance to be near a large stone or stump, or some heavy object low down and firmly imbedded in the ground, take a position directly to the east of it, lying prone upon the earth, head toward the object, protecting the former with your folded arms. This advice is given in the event of extreme exigencies where other and better opportunities have been forfeited. It is better, if possible, never to trust yourself behind or about any object located within the center of the storm's path; by all means not a tree or any object that rises some distance above the surface of the ground. If forced to remain in your house and where you have no cellar, always take a position against the west or south wall (better the former) either prone (face downward) upon the floor or standing with your back to the wall.

In any building always take your final position on the first or ground floor. Never stand or lie in front of a door or window, or near a stove or heavy piece of furniture. Make every effort to get into the west room, and if possible before the onslaught remove therefrom all furniture, at least from the western portion. Always shut tightly every window and door in your house or other building in which you may be located at the time of the storm. You should never let doors and windows remain open during any violent storm. Never take refuge in a forest, in a small grove of trees, in an orchard, or near a fence of any kind, unless all these obstructions are entirely out of the line of the storm.

If possible, always open your buildings and let your stock out, driving them to the north. In this matter of caring for stock (which should not be neglected if otherwise possible) always drive them from your buildings to the (as a rule) northward. Try and perform this duty on the first indications of the character of the storm, though not until you have assured yourself of the probable course of the tornado-cloud. Of course it is quite possible that the tornado-cloud may pass to the north of your buildings; in that event your stock should be driven southward, and vice versa.

PRIZE TORNADO-CAVE.

Through the courtesy of the Burlington Insurance Company, of Iowa, we are the first to publish the design of John R. Church, architect, of Rochester, New York, which was the one selected by the author (empowered by the Burlington Company to adjudicate the claims of competitors and award the prize) from 122 designs submitted in competition for the $200 prize offered by that company.

These plans and specifications, and all that pertains to them, are protected by special copyright, and are the property of the Burlington Insurance Company.

DESIGN FOR A TORNADO-CAVE, BY JOHN R. CHURCH, ARCHITECT, ROCHESTER, N. Y.

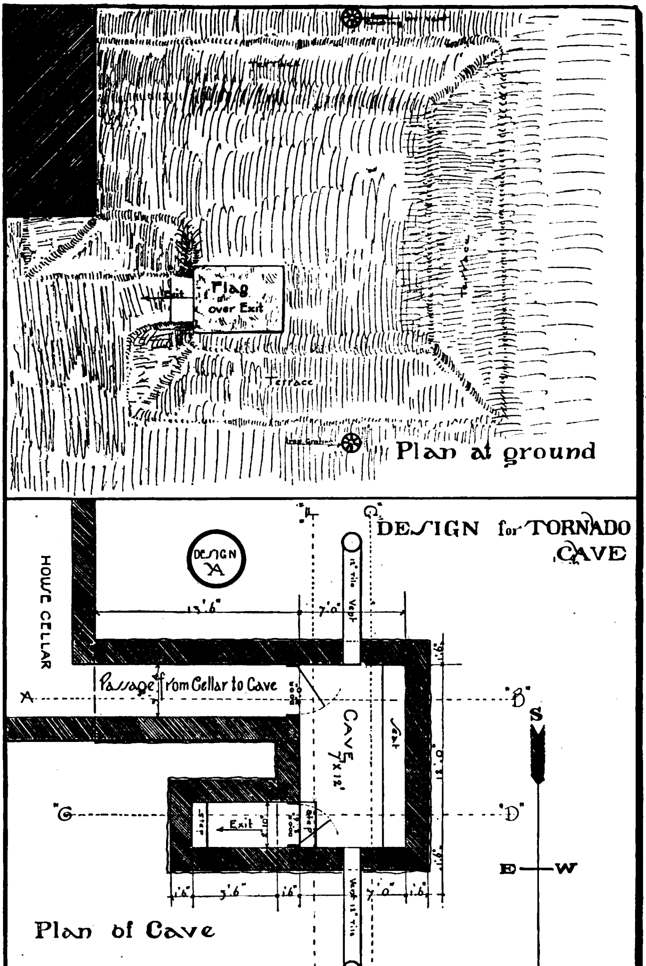
The general design of the cave is indicated by the accompanying drawings.

The cave is designed for two different methods of entrance. In design "A" the entrance is from the cellar of dwelling. In design "B" the plan is intended for a dwelling without cellar, the entrance to cave is from a room in the rear part of dwelling and through trap-door in floor.

The drawings indicate walls of stone 18 inches in thickness; it is intended that they should be laid up in mortar of good quality cement and clean, sharp sand. The excavation should be made large enough to allow the walls to be pointed and plastered on the outside with cement mortar, to prevent water from coming through them. The walls should be started on a bed of cement mortar 1 inch thick.

In a country where stone is more expensive than brick, an 8-inch brick wall can be substituted for the stone wall, plastering the wall on the outside with cement mortar and laying the brick in same kind of mortar.

The floor of the cave and passages to be paved with one course of "hard-burned" brick, these to be laid on a bed of cement



SCALE.—Twelve feet eight inches to the inch.

mortar 2 inches thick, and the joints to be thoroughly grouted with cement.

The construction of the roof to be with iron beams and 8-inch arches of "hard-burned" brick as shown, the brick to be laid in cement mortar, top to be leveled up and sloped as indicated with concrete, and the whole to be covered with a coating of best roofing pitch ; this to be applied hot and the roof made water-tight. Roof of the passage to be constructed in same way.

Iron beams indicated should be 6 inches, 40 lbs. per yard, with 4 x 6 inch angle-irons laid on the walls as shown – to provide skewbacks for the arches—angle irons to weigh 30 lbs. per yard. The bolts to be 1 inch in diameter, and to be fixed as indicated. Roof of the "exit" to be covered with flag-stone 6 inches thick.

For ventilation two lines of 12-inch, salt-glazed, vitrified tile are provided, these to connect with outer air as indicated, tile to run up above the ground about 6 inches and to have cast-iron grating in top.

The doors to be made of 2-inch matched plank, hung with strap-hinges, battened, and provided with bolts, latches, etc.

An exit to open air is provided in addition to the entrance to cave from dwelling; this can also be used for an entrance if desired

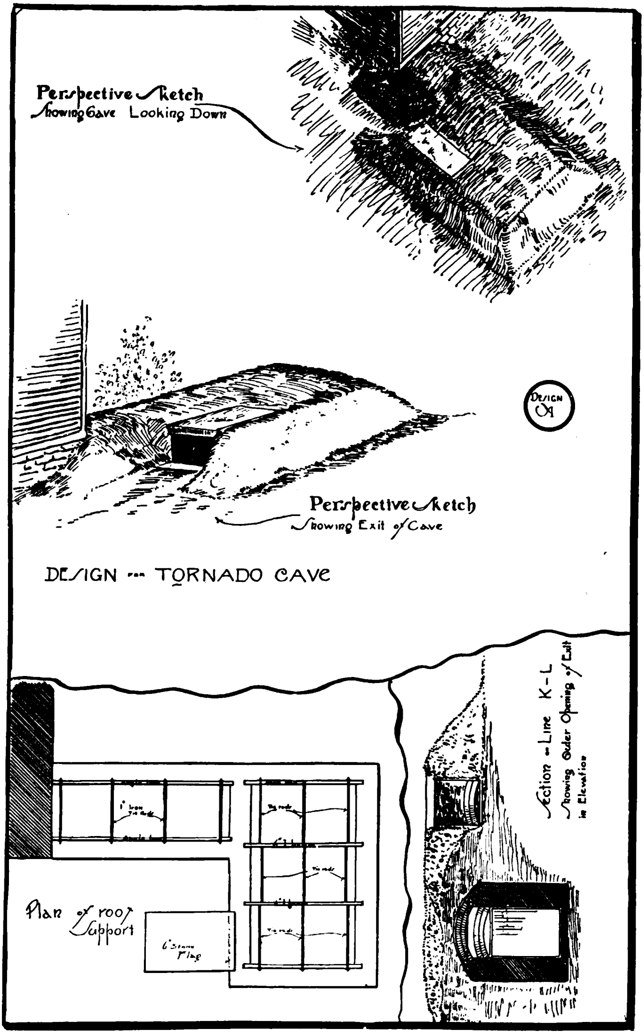
SPECIFICATION

Of materials and labor required in the construction of a "tornado-cave" for Mr. ———, to be located on the west side of his dwelling, situated -———, in accordance with accompanying drawings prepared by John R. Church, architect, 54 Osburn House Block, Rochester, N. Y.

DIMENSIONS.

The size of the cave to be seven feet by twelve feet inside, and the height to be six feet six inches in the clear, passages, etc., all to be as shown on the drawings, which consist of—

(1.) Plan of the cave at ground.
(2.) Plan of cave below ground.
(3.) Four sections of cave on different lines.
(4.) Perspective sketch of entrance.
(5.) Perspective sketch of interior. Drawings have the scale indicated on them.


Perspective Sketch
Showing Cave Looking Down
DESIGN
Perspective Sketch
Showing Exit of Cave
DESIGN — TORNADO CAVE
Section — Line K-L
Showing Outer Opening of Exit
in Elevation
Plan of roof Support
6" Stone Flag

EXCAVATION.

Excavate for the cave, the passage from cellar or house, and for the exit-passage, all as shown on the drawings. The excavation to be made large—at least eighteen inches outside of the walls on all sides—so that the walls can be plastered on the outside.

The excavation to be carried down to seven feet below the surface of the ground, as indicated on the sectional drawings. After the walls have been plastered as hereinafter specified, and the mortar is dry, pack the earth in against the walls, and after the roof is on cover the same with earth, as shown by the drawings, and slope it from the top of cave as indicated.

STONE-WORK.

The walls of the cave to be of stone, eighteen inches thick; these to be built with good, flat, building stone, the walls to be laid by and full to a line both faces, and the walls to be properly flushed and pointed; the walls must be filled solid, leaving no empty spaces in them.

The stone walls are to start four inches below the finished line of floor of cave, lay the footings of same on a bed of cement mortar not less than one inch thick, the same extending well outside of the walls.

All of the stone work to be laid in mortar made of clean, coarse, sharp sand and a good quality of cement, mixed in the proportion of three of sand to one of cement; all to be mixed dry, and only wetted up as fast as used.

The outer face of the walls to be plastered with a good coat of cement mortar, the same to be carried down to the mortar under the wall, the mortar made in same manner as specified above for the stone-work.

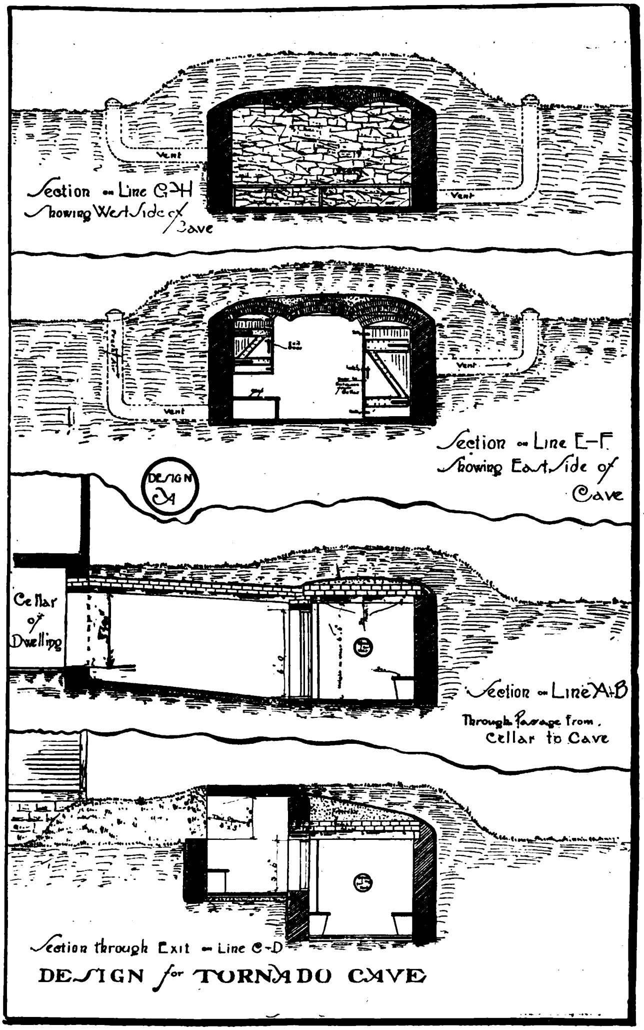
If brick is used for the walls instead of stone, substitute the following for the above :—

BRICK WALLS.

All brick used in the construction of the cave must be "thoroughly hard-burned brick," no soft brick to be used in any part.

Start the brick walls on a bed of cement mortar at least one inch thick, and four inches below the finished floor of cave; this mortar to be made of clean, coarse, sharp sand and a good quality of cement, in parts of three of sand to one of cement.

Construct the brick walls in the best manner, all to be eight inches thick, built of hard-burned brick laid in cement mortar; the walls to be properly bonded with headers every sixth course, every course to be flushed solid, leaving no empty spaces in the walls—the inside of the walls to have the joints neatly struck, and the outer faces of the walls



DESIGN for TORNADO CAVE

must all be plastered with a good coat of cement mortar, the same to be carried down to bottom of the walls. All brick must be well wet before laying.

IRON-WORK.

Provide iron-work for the support of the roof, as shown by the drawing of same.

Support the roof of cave with two six-inch **I** beams weighing 40 lbs. per yard, to form skewbacks for the arches; place 3 x 5 angle-irons on the walls, and connect the whole with three lines of iron bolts one inch in diameter, the bolts to have nuts, etc.

Support the roof of the passage as shown, using 3 x 5 angle-irons on walls to form skewbacks for the arches, place one-inch iron bolts as indicated, the angle-iron to weigh 30 lbs. per yard.

ARCHES.

Construct the arches forming the roof of the cave as shown by the sectional drawings, using only hard, well-burned brick, no soft brick to be used; the arches to be two "row-locks," as indicated, and to be built on proper centering. The brick must all be soaked in water before using, to be laid with cement mortar, and the joints to be made close, and filled solid, leaving no empty spaces in them. All joints to be well slushed up with cement mortar.

Fill in on top of the roof of cave and passage, as shown on the sectional drawings, with concrete made of clean, coarse, sharp sand, broken stone-chips, or coarse gravel, and a good quality of cement; the top of the cave and passage to be of convex form as indicated, so that it will shed water. Top to be made flush and smooth.

PITCH.

The whole top of cave and passage to be covered with a good heavy coat of good roofing pitch, this to be applied hot and the roof to be made water-tight thereby.

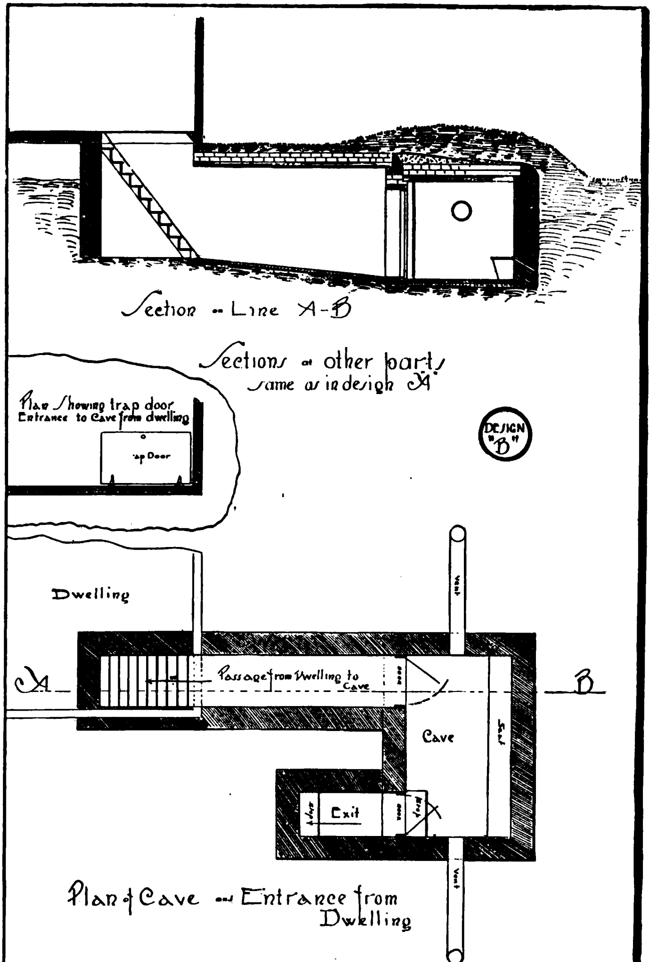
FLAG-STONE OVER EXIT.

Provide and place over the exit-passage, as indicated on the drawings, a flag-stone not less than five inches thick; set same in cement mortar, and pitch the joints to make water-tight.

Provide a stone sill to the outer exit-opening; this to be four inches thick.

FLOOR OF CAVE.

Spread a bed of cement mortar two inches thick on the ground in the cave and the passages; this to be leveled off true and smooth, and covered with one course of hard-burned brick laid flat, the joints of which are to be thoroughly grouted in cement.



Design for Tornado Cave

VENTILATION.

For ventilation of the cave provide two lines of twelve-inch, salt-glazed, vitrified tile; provide 1-4 bends as shown, and carry tile up to six inches above the finished grade, as shown by drawings; the joints must all be made tight with cement, and the outer openings of the tile to have iron gratings as shown.

DOORS.

Construct two doors as indicated on the plans, these doors to be of two-inch planed and matched pine stuff; the same to be battened on the back, the same put on with screws, and to be hung to the frames with large, heavy T hinges.

The door-frames to have sills of oak, the jambs to be of pine two inches thick, the same rebated for the doors; the jamb to which the door is hung to be four inches wider than the others; this to project into the cave, so as to secure the hinges to it. Provide the doors with heavy thumb-latches, iron bolts, staples, and a padlock to each door.

The head-jamb of the door-frames and the sills of same to project three inches into the walls at sides.

Provide lintels of segment form, as indicated on the drawings, over door-openings on which arches of brick are to be turned as shown.

SEAT AND STEPS.

Construct seat and steps as shown on the plans; all of sound dry pine, two inches thick, to be planed and constructed and put up in a good, substantial manner.

OPENING IN CELLAR WALL.

Cut opening through the cellar wall of the dwelling as indicated, for the passage to cave, properly fill out the jambs of the opening and finish plumb and true.

FOR A HOUSE WITHOUT A CELLAR, INCLUDE THE FOLLOWING :—

The wall of the passage to be carried under the house as shown on the plan.

Cut out the floor-timbers, floor, etc., in the house, and frame trimmers, headers, etc., as required for the proper support of the floor.

Construct trap-door as indicated, with flooring same as in the room, the door to be battened on the back, the battens to be put on with wrought nails, the door to be hung with heavy 8-inch T hinges and trimmed with ring and staple to open.

Construct a flight of stairs leading to passage, as indicated on the plan; the stringers to be of two-inch pine plank and the treads of 1 1-4

inch pine stuff, the edges chamfered 3-8 inches, the treads to be housed into the stringers, and the whole well nailed and put together in a substantial manner.

SPECIFICATION

For the construction of the walls of wood in the place of brick or stone.

WALLS.

Construct all the walls of cave and passages with 2 x 4 inch pine stuff, laid the flat way, all well spiked together, the joints to be properly broken at the angles and corners; the stuff to be placed horizontally and to make walls four inches thick without exterior covering. This stuff should all have a good coat of coal-tar, applied hot, and same to cover all four sides of the stuff; this to preserve the wood.

Cover the outside of the above walls with 7-8 planed and matched pine stuff, this also to be coated on both sides with coal-tar; these boards to be placed vertically, and all well nailed.

ROOF.

Construct the roof with 2 x 8 stuff, placed on edge and close together, forming a solid roof eight inches thick in the center; the ends of same to be cut down to six inches, so as to form a pitch for the roof, which will slope from the center to either side. Cover the top of roof with 7-8 matched pine stuff, all well nailed; the above roofing to be covered with coal-tar, same as specified for the side walls. Cover the roof-boards with a good coat of roofing pitch. Construct the roof of the passages in the same manner, using 2 x 6 stuff and cutting down to 4 at ends. The floor, arrangement for ventilation, doors, etc., to be the same as specified for cave built with stone or brick.

ESTIMATES

Of cost of tornado-cave, in accordance with design for same presented by John R. Church, architect, Rochester, N. Y.

NOTE.—Estimates are based upon following prices for materials and labor :—

Excavation	$ .30 per cubic yd.
Building stone	6.00 per cord.
Brick	8.00 per thousand.
Sand	1.50 per cubic yd.
Cement	1.25 per bbl.
Iron	.03 ½ per lb.
Pine lumber (rough)	18.00 per thous. ft.
Tile	.40 per ft. lin.
Pitching roof	.05 per sq. ft.
Labor, mason	3.00 per day.
Labor, laborer	1.50 per day.

Estimate for cave connected with house having cellar. Walls of cave of stone. Includes labor.

100 cubic yds. excavation	$ 30.00
Stone-work, 50 perches (of 16 ½ cubic ft.)	112.50
Concrete and plastering	30.00
Flooring, 600 brick	8.40
Roof, 2,700 brick	37.80
Flag-stone over exit	12.00
Stone sill at exit	2.00
Pitching roof, 300 feet	15.00
Iron-work, 750 lbs	24.38
Tile for vent	10.00
Laying same	3.00
Gratings for vent opening (2)	2.00
Doors, seats, etc	12.00
	$299.08

Where the cave is to be used independent of any building, and passage to house is omitted, deduct from the above figures the sum of $62.30, making the estimated cost of cave under those conditions $236.78.

Estimate of the cost of cave with brick walls connected to house having cellar. Labor included.

85 cubic yds. excavation	$ 25.50
8,100 brick in walls	113.40
600 brick for floor	8.40
2,700 brick for roof	37.80
Flag-stone over exit	12.00
Stone sill at exit	2.00
Pitching roof, 300 feet	15.00
Iron-work, 750 lbs	24.38
Concrete and plastering	30.00
Tile for vent	10.00
Laying tile and trenching	3.00
Gratings for vent	2.00
Doors, seats, etc	12.00
	$295.48

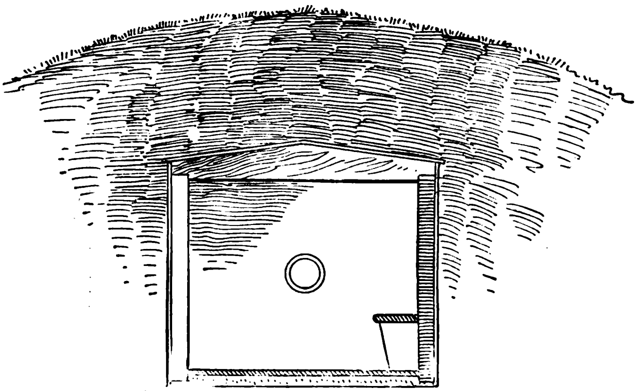
Where the cave is to be used independent from any building, and the passage to cellar is omitted, deduct from the above figures the sum of $60.88, making the estimated cost of cave under those conditions $234.60.

Estimate of cost of cave with brick walls, connected with house having no cellar. Labor included.

110 cubic yds. excavation	$ 33.00
10,200 brick in walls	142.20
600 brick for floor	8.40
2,700 brick for roofing	37.80
Concrete, plastering, etc	32.00
Flag-stone over exit	12.00
Stone sill at exit	2.00
Pitching top of roof, 300 feet	15.00
750 lbs. iron in roof	24.38
Tile for vent, 23 feet, 3 bends	10.00
Laying tile and trenching	3.00
Gratings for top of tile	2.00
Doors, seats, etc	12.00
Stairs, trap-door in house, etc	10.00
	$344.38

Estimate of cost of cave having stone walls, connected with house having no cellar. Includes labor.

126 cubic yds. excavation	$ 37.80
Stone-work, 62 perches (of 16½ cubic feet)	139.50
600 brick in floor	8.40
2,700 brick in roof	37.80
Concrete and plastering	32.00
Flag-stone over exit	12.00
Stone sill at exit	2.00
Pitching roof	15.00
Iron-work, 750 lbs	24.38
Tile for vent	10.00
Laying and trenching same	3.00
Gratings for vent	2.00
Doors, seats, etc	12.00
Stairs, trap-door, etc	10.00
	$345.38



Section of Cave. Woodconstruction.

Estimate of cost of cave, walls constructed of wood, and connected with house having cellar.

Excavation, 85 cubic yds	$25.50
3,000 feet rough pine	54.00
1,000 feet matched stuff	20.00
Labor on above	35.00
Tarring roof and lumber	20.00
Floor, brick and cement	12.00
Tile for vent, laying same and grating	15.00
Doors, seat, etc	12.00
	$193.50

Where the cave is to be used independent from any building, and the passage to house is omitted, deduct from above figures $39.00, making the estimated cost under those conditions $154.50.

For walls constructed of wood as above, connected with house having no cellar, add to above figures the sum of $25.50.

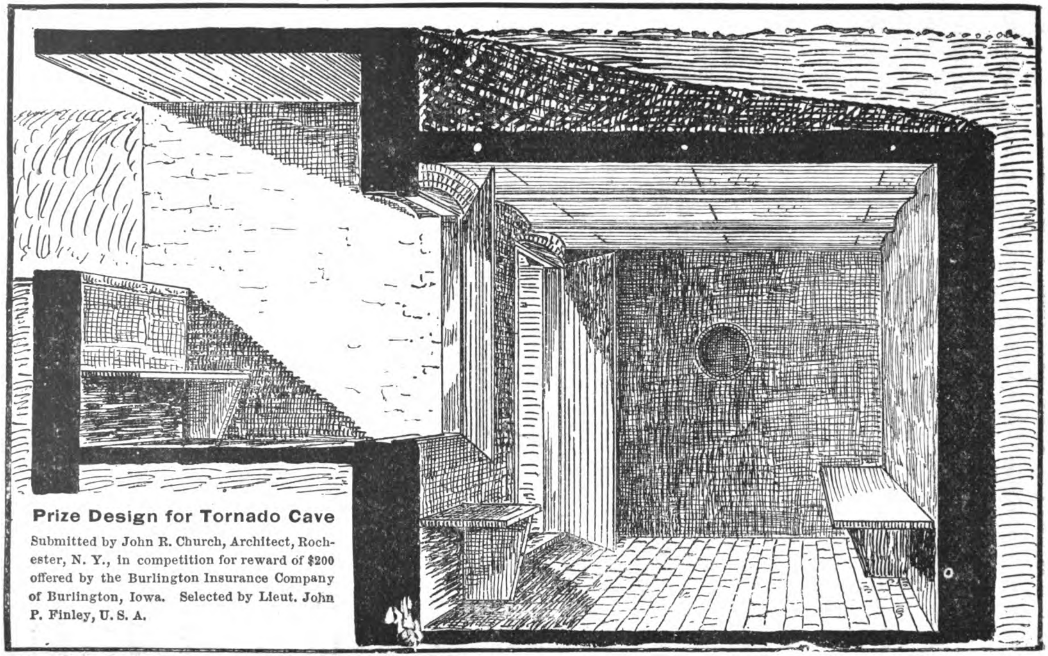
Remarks upon the Construction and Use of Tornado-caves, by Lieut. Finley.

The importance of securing absolute protection against bodily injury from the violence of tornadoes cannot be questioned, and there are few people who now speak lightly of the necessity of resorting to extraordinary means in the presence of the king of storms. The word "extraordinary" is used advisedly, because ordinarily man obtains immunity against the fury of the elements by refuge in the usual forms of habitation; but the dreadful force of the tornado compels us to ignore all places of security where the structure rises above the surface of the ground.

Let us take an example, illustrating the force of the wind. Assume the progressive velocity of the storm to be twenty-five miles per hour. Suppose a house 24 x 30 feet on its foundation exposes a plane surface to the wind of 720 square feet. Twenty-five miles per hour is equivalent to about two pounds pressure upon each square foot of surface, presented at right angles or perpendicular to the direction of the wind. On 720 square feet of surface the pressure exerted at right angles to it would be 1,440 pounds. This is not enough force to move the building, because it is much less than the actual weight of the structure, and therefore insufficient to overcome its point of stability. But twenty-five miles per hour is simply a brisk wind.

Air moving with a velocity of 100 miles per hour against the building here referred to would exert a pressure of 21,600 pounds upon its exposed surface of 720 square feet. With a velocity of 500 miles per hour the pressure would be increased to 486,000 pounds, or 243 tons. This enormous pressure is but about one-half of that which would result in the case of a perfect vacuum in the tornado's vortex. In a perfect vacuum, the air rushing into it would move at the rate of about 1,400 feet per second, which would be nearly equivalent to a velocity of 1,000 miles per hour. The pressure upon each square foot of surface exposed to such a velocity would be about 2,700 pounds per square foot, or if thrown upon the entire building, that is, 720 square feet of surface, 1,944,000 pounds, or 972 tons.

The force here assumed is force acting only in right lines. But when it is understood that in the actual tornado the forces in play are exerted both in right lines and in curved lines, the destructive power is seen to be of almost incalculable fury and energy. In the majority of instances the determinations as to the force of the wind in a tornado have ranged between 100 and 500 miles per hour. Theoretical velocities of over 2,000 miles per hour, based upon certain assumed atmos-



Prize Design for Tornado Cave

Submitted by John R. Church, Architect, Rochester, N. Y., in competition for reward of $200 offered by the Burlington Insurance Company of Burlington, Iowa. Selected by Lieut. John P. Finley, U. S. A.

Perspective sketch showing interior.

pheric conditions, have been deduced. Such velocities are mathematically possible, but not meteorologically probable. What has now transpired shows the absolute and undeniable necessity for an underground retreat to secure protection from the tornado.

HINTS.

1st. Locate the cave west of the house, so that if the building is destroyed the débris will not be as likely to be thrown upon it, the storm always coming from the southwest quadrant.

2d. The entrance and exit to the cave should be east of the cave proper and connected with it by a tunnel or chamber, and securely protected from injury.

3d. It is preferable that the entrances should connect with the cellar of the house, or if there is no cellar, then by means of a trap-door within the house leading by a stairway to the underground chamber, which finally connects with the cave proper.

4th. The entrance way should have two doors, one at the beginning of the chamber or tunnel, and the other at the end opening into the cave, as precaution against the intrusion of fire and smoke, where the débris of the house might be destroyed by fire.

5th. The entrance and exit should be independent of each other, and the latter lead out to the open air by a short chamber with two doors, one exterior and the other interior, the latter opening into the cave proper.

6th. The roof of the cave should always be arched, because offering more resistance to the force of the wind and falling débris than a plane surface. The upper surface of the roof should be at least three (3) feet below the earth resting upon it. This precaution gives additional protection against driving timbers thrown by the force of the wind.

7th. The excavation for masonry work should be of sufficient depth to permit the upper surface of the roof of the cave to rest about one foot below the surface of the (surrounding) undisturbed earth. This arrangement, by allowing three feet of earth to cover the roof, will raise a mound of about two feet, which, while serving as a protection to the masonry, will also serve to turn the surface-water away from the roof of the cave.

8th. The earth covering the roof should be well pounded. It may be mixed with broken stone. The surface should be sodded or sown with blue grass. Every precaution must be taken to render the earth above the roof of cave proof against flying missiles and timbers, which are frequently driven several feet into the solid earth.

9th. Stone or brick, with Akron or Portland building cement, is the best material for purposes of construction.

10th. It is folly and false economy to build a cave without taking every precaution to prevent decay of materials used.

11th. Drainage. Particular attention should be paid to constructing the cave in such a manner that it will keep dry. If possible, a dry cave should be constructed by laying all masonry in cement mortar and carefully pointing the exterior of all walls, and then plastering on the outer faces with cement mortar.

The roof should take the convex form suggested, and should be covered with a good coat of coal-tar or roofing pitch.

The cave should never be connected with the house-drain, cesspool, or sewer, receiving waste from the house, on account of the difficulty of so disconnecting same as to prevent the entrance of sewer-gas into cave—as during the dry season the water-seal of the trap would be likely to be broken from evaporation and other causes.

The cave should not be connected with a cesspool receiving waste from the house, on account of the possibility of same overflowing into the cave.

12th. Where practicable, the entrance and exit doors which open into the cave proper should be of iron, or oak covered with sheet iron.

13th. Careful attention should be given to secure complete and undisturbed ventilation of the entire cave.

14th. During the season when tornadoes are most likely to occur, the cave should be provided with all things necessary to place it in readiness for occupation at any moment of night or day. Every precaution should be taken to keep the entrance and exit ways free from all obstacles that might prevent or delay the immediate use of the cave. The cave should always be provided with the means of lighting it, say, safety-lamps or lanterns.

15th. Every one constructing a tornado-cave should bear in mind the necessity which may occur of their being compelled to use it as a home for a considerable time while repairing or building anew from the ruins of the storm. Therefore, where it is possible, it is of the utmost importance to erect the tornado-cave with care, thoroughness, and a due regard to comfort. The poor man, if he must build slowly for lack of funds, should build exceedingly well, while the rich can construct rapidly, thoroughly, and with every regard for comfort and adornment. But in either case the absolute protection from injury and loss should be the same, because the poor man cannot afford to waste money and time, and subject himself and family to great danger, by reason of a hasty and improperly constructed cave.

16th. During that season of the year when tornadoes are not likely to occur, the tornado-cave may be turned to practical account for the storage and safe keeping of many things necessary for household use.

17th. The cave proper may be constructed in circular form, with convex roof, as perhaps being more durable and economical of space than the angular form with convex roof, but whatever the particular fancy of the builder may dictate, let the work be done thoroughly and with the best materials.

With regard to the protection of life and property in the many small towns, and even cities, liable to be visited by the devastating tornado-cloud, what has already been suggested in the manner of north and south movements, dug-outs, and cellar-caves will, of course, apply here. Where, as in a village or city, a large number of persons are congregated, each intent upon his or her particular business, it is hardly to be expected that they will have the leisure to observe, or be inclined to give any attention to the face of the sky. Should it chance that any person watched the atmospheric changes and received indications of the approach of a tornado-cloud, he might not think it his duty (probably forget it in his excitement) to warn others of the impending danger, or provide for the safety of more than his own family. Of course, in any event it is natural to suppose that he would first secure his own household. This supposed case is a very probable one; at least nine times out of ten we find that towns are devastated without apparent warning, and the unfortunate people, startled from their imagined security, are killed in their struggling efforts for escape. Some provision should be made for the mass of inhabitants who are performing their various duties in and out of doors, and who by reason of their peculiar situation or labor could not, if they would, ascertain the prognostics of the sky.

With regard to this matter we will offer a few suggestions which may not be amiss. On any day when there is presaged in the weather conditions evidence of the probable approach of a violent wind-storm, it should be the duty of those in authority to deputize certain intelligent persons to watch the character and approach of the storm and, if a tornado, to give timely warning of its advance to the various families in their respective wards, and take charge of the removal of persons and property to places of safety. The church and school bells might be rung in a peculiar manner as a signal of warning. These men should be cool, brave, active, and judicious. They should understand the situation, know precisely what is needed and how to supply it. All persons should at the proper time appreciate the situation of those in authority and avoid confusion by a strict compliance with orders.

The signs (as before described) of tornado-cloud formation and approach are distinct and sufficiently suggestive to afford opportunity for timely and concerted action. The time for action will necessarily be limited, and the watch need not commence until there is every reason to believe that such a course is absolutely necessary. Some persons may be disposed to smile at the novelty and minuteness of this arrangement, or at the idea of employing weather-guards at Western towns. I will venture to say that these smiles will not appear on the faces of persons who have experienced the irresistible and overwhelming violence of a tornado. I have never detected levity or indifference among those who were left to tell the tale of distress in any of the many almost annihilated towns of the West. You may smile or wonder at the thought of hardy, brave men who have, without flinching and in support of their country's honor, faced the red-hot belchings of a score of batteries, who now at the sight of a threatening cloud or the experience of a brisk wind, make a bold dash for places of safety, or, throwing themselves upon the ground, clutch at the first object within reach. Such is the abject terror which possesses all alike after the experience of a tornado.

Immediately following and for some weeks after the occurrence in Kansas and Missouri of the violent tornadoes of 1879, hundreds of people along the tracks and in the vicinity of the storms hardly went to bed, but remained dressed and, with their lanterns trimmed and burning, watched intently every foreboding appearance of the sky. Every dark cloud or sudden increase of the wind was calculated to affect them with an indescribable terror which could not be allayed until every vestige of the supposed danger had vanished. This is not the pitiful tale alone of Kansas and Missouri sufferers, but wherever the dreaded tornado makes it way, be it in Michigan, in Mississippi, in Georgia, in Massachusetts, or in Minnesota, the awful roar and power of its march strike all life dumb with fear. A great deal can be accomplished towards allaying this fear by a dissemination of practical knowledge concerning storms and by a general effort among intelligent people to appreciate such information. All intelligent persons can and should become familiar with the various classes of storms and be qualified to detect their formation and approach.

There is no country on the face of the globe where meteorology can be studied with so much advantage, practically and scientifically, as in North America. The elementary principles of meteorology, especially in regard to storms, should be taught in every school, country, town, and city. In the colleges and universities an advanced course should be prescribed. Speculation regarding the weather is exceedingly rife, affecting every branch of the science and in a manner quite without precedent in the line of methodical knowledge.

Tornado prediction is no longer a mere possibility, but in many respects may be considered an accomplished fact. By this I do not mean absolute perfection, but reasonable success. The system of preparation and study which leads to the result is subject to improvement, both as to manipulation of charted data and the verification of forecasts; but it is believed that the work now in hand with the above end in view, will greatly enhance the present measure of success. Tornado predictions have been made daily, largely as a matter of study, but in part for the information of the public, through Signal Service official bulletins, since March 1st, 1884.

That all people may know and become impressed with the exceptional power and awful grandeur of the tornado, illustrations of its work in particular instances will be opportune at this time.

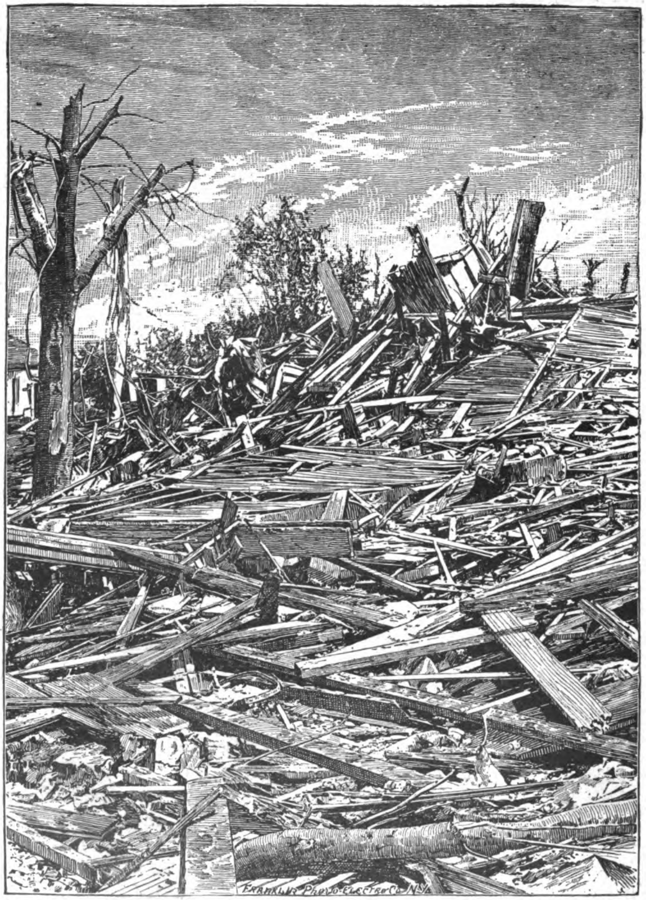
REPORT ON THE TORNADOES OF MAY 29TH AND 30TH, 1879, AT SALINE COUNTY, KANSAS. PROFESSIONAL PAPER OF THE SIGNAL SERVICE NO. IV., BY LIEUT. FINLEY.

On the 30th of May, 1879, at about 3 P. M., a tornado passed over a portion of Saline County, Kansas, concerning which the following graphic description was prepared by an eye-witness :—

"It rains so gently this afternoon that the weather is really enjoyable. Plants grow and flowers bloom as they never do when it is dry. The Solomon Valley seems almost a second Garden of Eden. A short time before the clock strikes three, hailstones begin to fall, which rapidly increase in size. We gather some of the largest and find that it takes six of them to weigh a pound. But notice that hail-cloud south of us! What wonderful contortions, evolutions, and twistings.

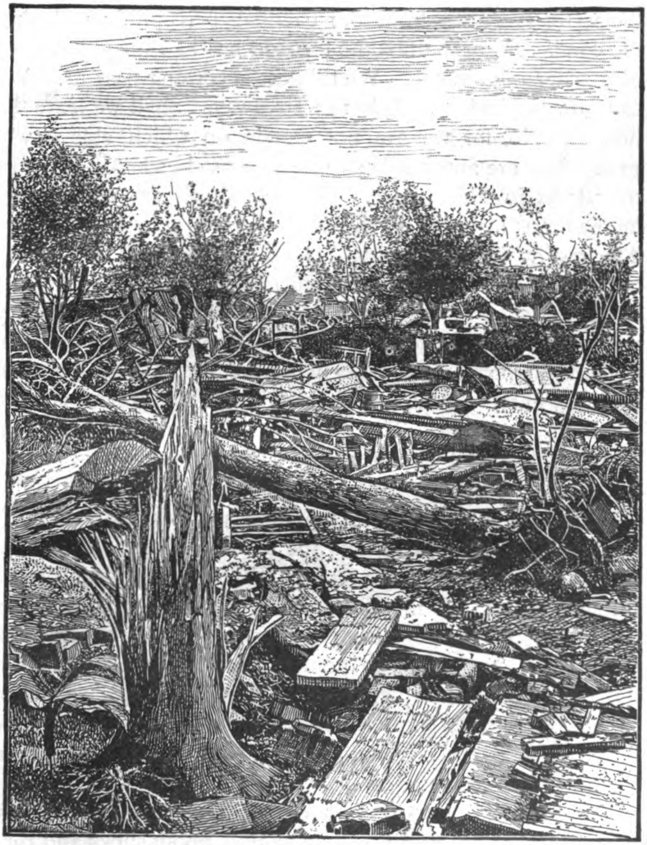
NOTE.—Pictures of the identical storms described are not obtainable, and, *per contra*, descriptions of the storms photographed are not at hand; but as one tornado is essentially the counterpart of another, we have adopted such pictures as we could get to illustrate the destructive force of these terrible meteors. There is no pretense that the pictures represent the events narrated other than in their characteristics. With this explanation no one need be misled by the juxtaposition of text and plate, which are in reality foreign to each other.

The hail that is falling from it is plainly visible from here, although it is four miles to the southwest. A few strips of cloud like whip-lashes hang from it.



Tornado at Grinnell, Iowa, June 17, 1882. View near the residence of Mr. Graham, looking northeast. From a Photograph.

"The cloud now revolves rapidly from right to left. We gaze at the magnificent scene with awe and wonder. The center becomes lower and lower, until it resembles a funnel



Tornado at Grinnell, Iowa, June 17, 1882. Débris of Dr. Ford's dwelling, looking east. From a Photograph.

The truth now bursts upon us. *It is a tornado!* We hear its awful roar like an earthquake or distant thunder. The fun-

nel rapidly descends till it reaches the earth. It moves rapidly northward. It rises, a dark cone ascends from the ground to meet it, and it descends. It strikes the river. All the water is drawn from the channel, perceptibly widening the cone. From the first the tornado has had the appearance of a waterspout at sea. We think it is coming near us. We can now see its fury. It is not far away. Shall we leave the house? No, for we are not certain on which side it will pass. We are apparently as safe here as elsewhere. We can only trust in Providence. The windows are nailed fast. Three of us lean against the door which is nearest the storm. The rest go into the cellar. It is about 4 P. M. A moment of breathless suspense and the storm strikes us. The timbers creak, the sides of the house sway in and out. Surely, they cannot outlast it. We hear no well-defined roar now, for on the outside, boards and other débris are fiercely clashing. All is dark within. In about fifteen minutes the storm is over. We leave the house. The center of the storm has passed to the west of us and we can see its dark form moving away in a northeast direction."

After leaving this point a neighbor was visited, and with what awful results! It makes the blood chill in the veins to rehearse the horrors of the scene. Wild and dreadful was the carnage of that hour. The buildings, the hard earnings of many years, were swept from the earth. A large, two-horse sulky plow, weighing 700 pounds, was carried a distance of thirty-five rods, breaking off one of the iron wheels attached to an iron axle $1\frac{3}{4}$ inches in diameter. Two stoves were found broken into small pieces, not any of them larger than six or eight inches square. Wagon hubs without a single spoke in them, wagon tires curled into fantastic shapes, pieces of clothing and bedding wound about sticks and timbers or scattered over the prairie, were the only signs of a once thrifty home. Upon the destruction of the house one of the daughters was carried by the wind 200 yards to the

northwest, and thrust head foremost into a barbed-wire fence. She was almost instantly killed, the clothing was stripped from her body, which was found covered with black mud and her hair matted with it. The posts along the fence for a

Tornado at Grinnell, Ia., June 17, 1882. General view looking in direction taken by the storm. From a Photograph. Dr. Grinnell's house in background. Shadow under the floor shows the place from which he took his wife and four children unharmed.

distance of twenty-five rods were covered on the south side with mud, straw, chaff, and bits of rags to a depth of nearly three inches, and near the bottom of the posts it was one

foot thick. It was plastered on as if thrown with the greatest velocity, requiring a sharp instrument and considerable physical exertion to make an impression upon it. Five of the posts were literally pulled out of the ground from a depth of twenty-eight inches. The wire was stripped from the posts and wound up into a ball. The eldest son was carried thirty rods to the northeast into a wheat field, his clothing torn into shreds, and his body covered with black mud. Another daughter had a piece of board driven nearly through the fleshy portion of her thigh, cutting a gash about seven inches wide; the board was pulled out of the flesh during the storm, probably by the violence of the wind. The ghastly wound, upon being examined by the attending surgeon, was found to contain pieces of nails, straw, mud, and splinters of wood. In all cases women suffered the most, as they were divested of their garments and left perfectly at the mercy of the flying débris that filled the air. The hair of all persons caught in the midst of the storm was so matted with mud that their heads had to be shaved in order to clean them. It seemed as if the mud belonged there naturally, and that the hair was but a mere usurper. Eyes and ears were also filled with mud, preventing the natural use of these senses. All of the wounds received were torn and jagged, and found mostly upon the back of the body and running upward. Two strangers passing by at the time of the storm stopped at the barns to seek shelter. One of them was repeatedly dashed to the ground and rolled about until death came to release him from his sufferings. The other took refuge in a straw-stack which was turned over upon him, and then finally scattered in every direction. When completely left to the mercy of the elements he was lifted in the air, how high he did not know, but while above the ground he came in contact with the tail or mane of a horse, which he grasped, but was finally separated from, coming down to the earth, with hat in one hand and hair in the other. A light, two-horse wagon, with

one horse attached, the other being killed by flying débris, was observed at a height of about 100 feet in the air. A large barn forty feet square, with sixteen-foot posts, was completely demolished, and every timber carried away from the

Tornado at Grinnell, Iowa, June 17, 1882. General view looking east. Wrecked buggy with spokes blown out of hub. From a Photograph.

foundation. Six horses were killed, two outright, and the others so seriously injured by flying débris driven into their bodies that they had to be shot. One animal was badly mangled about the body, and had nearly all of its bones

broken, having fallen from a considerable height, making a large depression in the tough sod of the prairie. Eighteen fat hogs, weighing from 300 to 500 pounds each, were killed outright, and six others died afterwards from their injuries.

Tornado at Grinnell, Iowa, June 17, 1882. Ruins of George Parse's residence. From a Photograph. Six wounded. Mrs. Parse blown 500 feet.

One hog weighing 300 pounds had a scantling seven feet long and six inches square driven lengthwise through its body. Another had a fence-board driven through it in the same manner, and still another had a sharp-pointed post

driven through the body from side to side; one was carried 300 yards out on the prairie. Two new lumber wagons were carried from thirty-five to fifty rods in different directions and torn to pieces. One of the wheels was carried a distance of one mile to the northwest. In other instances wheels were broken from the axles, the spokes twisted from their sockets, and the large, heavy, iron tires twisted into the most fantastic shapes. A log twelve feet long and ten inches

Tornado at Grinnell, Iowa, June 17, 1882. Ruins of Dr. Grinnell's residence. From a Photograph.

in diameter was carried 320 rods to the northwest. The front iron axle (1½ inches in diameter) of a top buggy was found bent double, the two ends crossing each other, and both wheels were torn off even to the hubs. The rear axle, with wheels attached, was carried one quarter of a mile to the northwest. A wooden sill eight by ten inches and sixteen feet long was carried twelve rods to the northwest. A cat was found half a mile northeast of the house in which she

was seen just before the storm, with every bone broken and the body crushed as flat as if it had been passed through a cider-press. Chickens were stripped of their feathers and carried long distances, one being found three miles to the northeast.

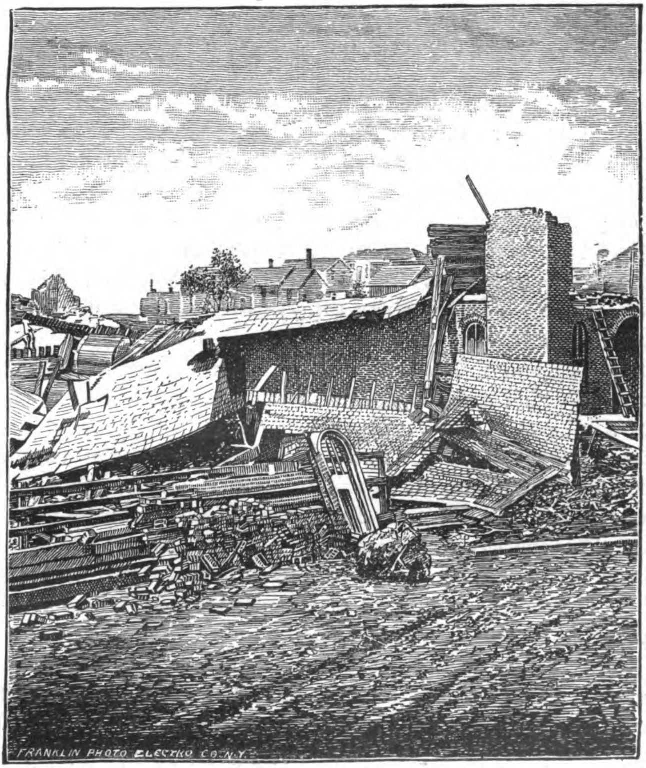
The iron mold-board of a heavy, wooden-beam plow was found driven into the ground so firmly that it had to be dug out. Osage hedges were filled with débris that defied removal without digging the bushes from the earth.

THE LEE'S SUMMIT TORNADO, JACKSON COUNTY, MISSOURI. MAY 30TH, 1879.

"At a little past 7:00 P. M. I saw the funnel-shaped cloud whirling terribly and approaching from Mr. Hutchin's. I was standing near the center of the south frame part of the house, and rushed to the south door to hold it, but before I could pull a chest to the door from a distance of ten feet the storm-cloud was upon us. The wind struck the south end of the house first, raising it from the foundation; then the log and frame parts to the north were struck upon the east side, also raising them from the foundation, when the top of the entire house fell in, and the whole confused mass was turned over twice to the northwest. It was left there but for a moment, apparently to give the whirling current time to pass around the barn to the west and south, which it did without injuring it, but throwing down the surrounding trees."

Returning to the house, which it did almost instantly, the violent southwest current carried all but the west side back to the north, a distance of several hundred yards, smashing everything into kindling-wood. No part of the roof and upper floors could ever be found. Mr. Warden, Jr., was carried with the house to the northwest, and while the current passed to the barn, was held between two of the floors and badly bruised, and on the

return of the current was carried to the north 200 yards. His father and younger brother pursued about the same course, except that the former was blown to the northwest



Tornado at Kansas City, July 17, 1880. Ruins of Carrigan's barn, cor. 17th St. and Madison Ave. From a Photograph.

and there remained with the west side of the house, while the latter was carried to a point within a few feet of his elder brother.

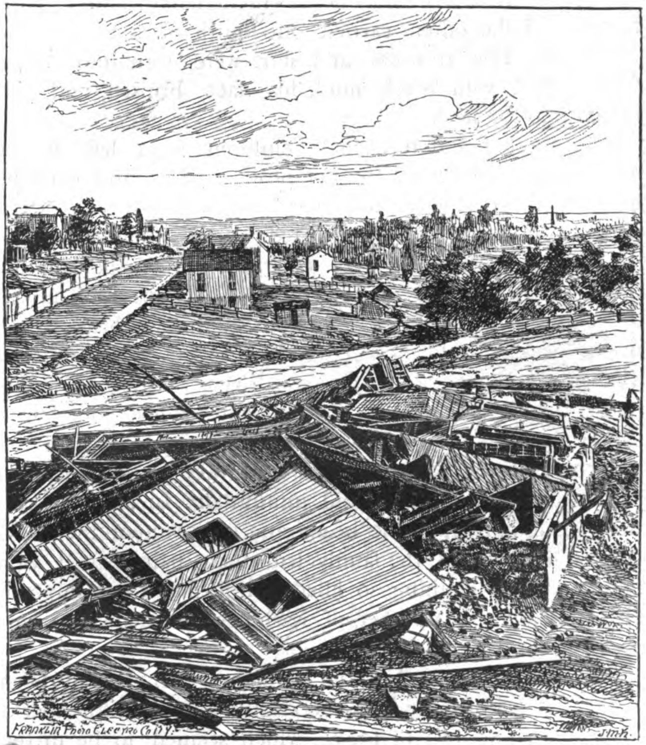
All of the parties were covered with mud from head to foot; eyes, mouths, and ears filled, and clothing torn into shreds. The elder son had his head and face cut, and shoes torn from his feet, one of them being found at the house, and the other carried one-fourth of a mile to the northeast. His trousers and shirt were torn into strips, hair matted with black mud, his face bruised, and dirt driven into the flesh.

The mother and two small children were left in the rubbish, the former having her head crushed, and her long hair, which reached below her waist, was partly cut and partly torn from the scalp, twisted into a rope, and found several feet from her body. That portion of the hair left upon the scalp was twisted into little wisps and mixed with mud. The baby was thrown to the southeast about twenty yards, and another child was carried to the west 112 feet, and two large splinters driven through its thigh, one of which came from Mr. Hutchin's house, one-fourth of a mile to the southwest, it being identified by the peculiar color of the paint upon it. A little girl was thrown six rods to the northwest and uninjured. In all cases cuts were made only upon the heads, and bruises upon the body. All the members of the family had their hair matted with mud and their clothing so filled with it, that it was impossible, even after a number of washings, to render the garments fit for use.

The bodies of most of the children, after having been washed daily for four days, were still covered with specks of fine dirt and bits of leaves, which seemed to be driven into the flesh.

The following will indicate some of the peculiar freaks of the storm: A carpet upon the floor of the log part of the house and securely tacked about the edges was taken up and carried out of the house without being torn. A new sewing machine was broken into forty or fifty pieces.

Fine feather beds were torn into strips, and the contents scattered broadcast over the country. Several garments were carried five or six miles to the northeast. An iron kettle holding fifteen gallons was broken into six pieces,



Tornado at Kansas City, July 17, 1880. Mr. Doggett's house, cor. 16th and Dripps Sts. From a Photograph.

and scattered about in several directions. A ten-gallon keg filled with vinegar was carried to the northeast forty rods. A large iron-bound trunk, fitted with an extra heavy lock, was torn to pieces and the lock found a half mile to the

northeast, sticking into one of the rails of a fence. Several photographs, which were known to have been securely placed in an album which was packed in the trunk, were found on the ground, a distance of over four miles to the northeast. A vest belonging to Mr. Warden and containing his watch, was carried out of the house. The watch, becoming separated from the vest, was carried by the wind fifty yards to

Tornado at Kansas City, July 17, 1880. Mr. Post's house, 19th and Mercer Sts. From a Photograph.

the northeast, and found covered with mud. The vest was carried to the east a distance of twenty yards. Several chickens were carried to the northeast, a distance of about one mile, and entirely stripped of their feathers. Two stoves were broken into small pieces, but one standing near the middle of the house escaped uninjured.

Tornado at Rochester, Minn., Aug. 21, 1886. Street view. Debris in Tornado's path. From a Photograph.

Heavy bed-quilts were so filled with mud that when dry they were as stiff and hard as boards. A lumber wagon was carried to the northwest ten rods, the box torn to pieces, and nearly all of the spokes taken out of the wheels. An iron-beam plow, standing twenty-five feet west of the house, was not moved or injured, and a seed-drill and harrow, near the barn, were also untouched. The débris from the house was scattered over a region of country one mile wide by five miles long. The path of greatest destruction was eighty rods wide, but fences were torn down for a breadth of nearly two miles.

Another dreadful disaster in the course of this storm occurred at the house of the ill-fated Harris family. It was situated in a little ravine near one of the branches of Sni-a-bar Creek, one-half mile east of Blue Springs, and sixty feet west of the storm's center. The family, consisting of father, mother, and four children, ran out of the house on the approach of the storm, the former and one or two of the children first moving to the northwest, but thinking that the cloud was coming directly towards them in that position, they turned back to the east, and by the time they had reached a point about on a line with the storm's course, they were struck by it.

The father and baby were carried into a field northeast of the house, a distance of 150 yards, covered with mud and bruises, and found in the agonies of death.

The mother, who had not succeeded in getting as far away from the house as the two former, was carried to the east seventy-five yards, and lodged against a small tree, around which her body was partially twisted. Her skull was crushed, and she died in a few minutes after being found. Her clothes were stripped from her body, which was bedaubed with mud from head to foot. One girl, eight years old, was found dead and mangled in the center of the storm's path, a distance of fifty yards northeast of the house. One boy was blown into a straw-stack, a distance of forty-five yards to the

Tornado at Rochester, Minn., Aug. 21, 1883. Ruins of a School House. From a Photograph.

northeast. A little girl was found eighty yards to the northeast, lying in the center of the storm's path. The two latter were not dangerously injured.

Those who examined the bodies of the dead, among them a physician, stated that after they were washed the entire surface was found to be ecchymosed; or, in other words, they had been so severely bruised and dashed about by the violence of the wind, that the flesh was nearly black by the settling of the blood in the tissues of the skin.

The ground upon which the house stood was swept as clean as if scourged by fire. There was hardly a vestige of clothing anywhere to be found. Now and then a small rag could be seen fluttering from some tree-top, caught upon a rail fence, or wound around some broken piece of timber.

The creek, about half a mile southeast of where the house stood, was found choked up with a mixture of straw, rags, feathers, kitchen utensils, rails, boards, household furniture, and pieces of farming implements. Wagon hubs were to be found with every spoke gone, some broken off and some pulled out. Two heavy quarter-inch wagon tires were twisted into knots. The iron mold-board of a plow, one-half inch in thickness, was broken in two, and one of the parts driven into the ground a depth of 9½ inches. There was not a single farming implement or article of furniture that was not rendered unserviceable.

TORNADO AT MARSHALL COUNTY, KANSAS, MAY 30TH, 1879.

The following relates chiefly to some of the dreadful experiences in the great tornado of May 30th, 1879, at Irving, Marshall County, Kansas.

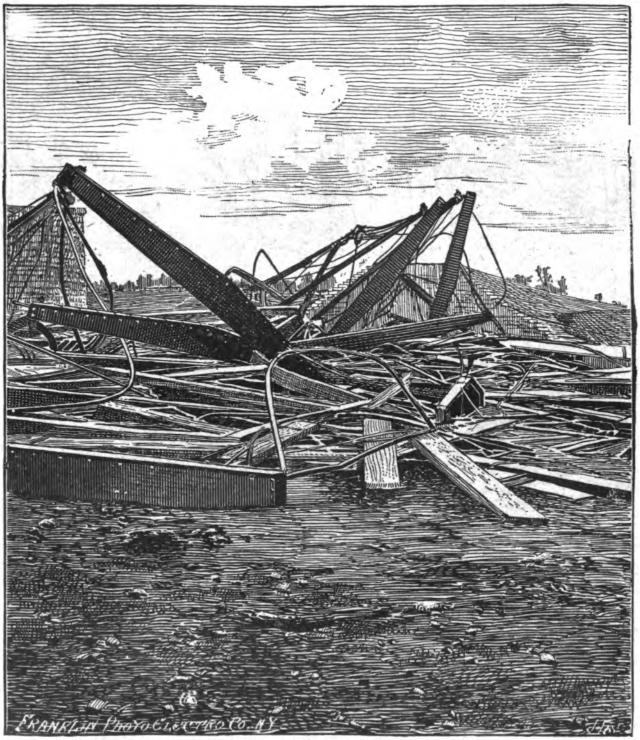
"The funnel-cloud now swept on a mile and a half over the valley beyond the town, scattering fences and twisting off small trees until it reached the Big Blue River at a point about 800 feet south of the large iron bridge. In crossing the river the clouds struck the heavily wooded bluffs on the eastern bank, rising from 75 to 150 feet, and turned imme-

diately up the river, striking the bridge squarely from the south, which it lifted bodily from the two stone piers and one abutment, and dashed it into the river. So completely

Tornado near Connersville, Ind., May 14, 1883, about 7:00 P. M. Ruins of an iron bridge lifted from abutments and dashed into the river below. From a Photograph.

twisted into shapeless ruin was the large mass of iron rods and stringers that it entirely disappeared from view in a few

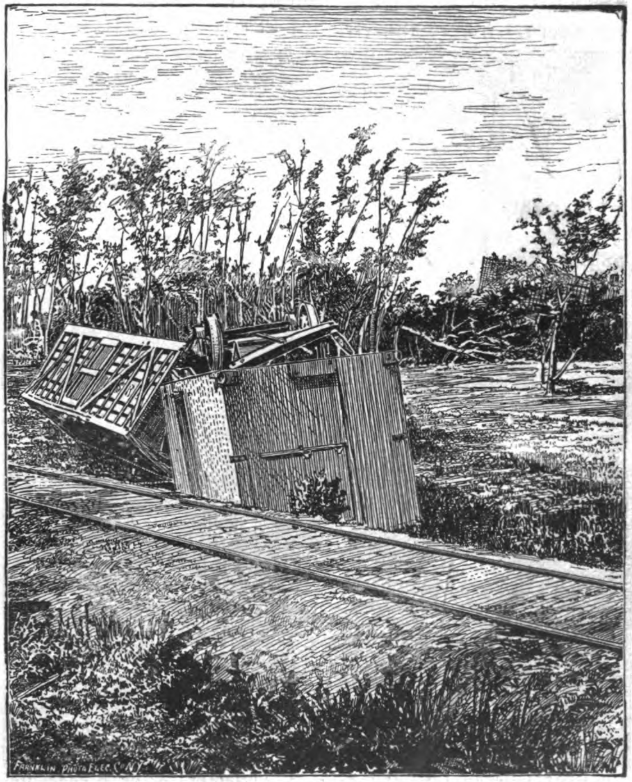
feet of water. The superstructure rested upon a heavy stone abutment at the east end, and upon two stone piers rising 22 feet above the water, one in the center and the other at the western extremity of the first iron span. From this pier to the western bank of the river, 140 feet, a wooden trestle-



Tornado near Connersville, Ind., May 14, 1883. See also page 87, another view of same bridge. From a Photograph.

work completed the structure. Thirty feet of the eastern end of this trestle was carried away with the iron spans and deposited in the river. Where the wooden portion separated, timbers 10 to 15 inches square, fastened with heavy iron

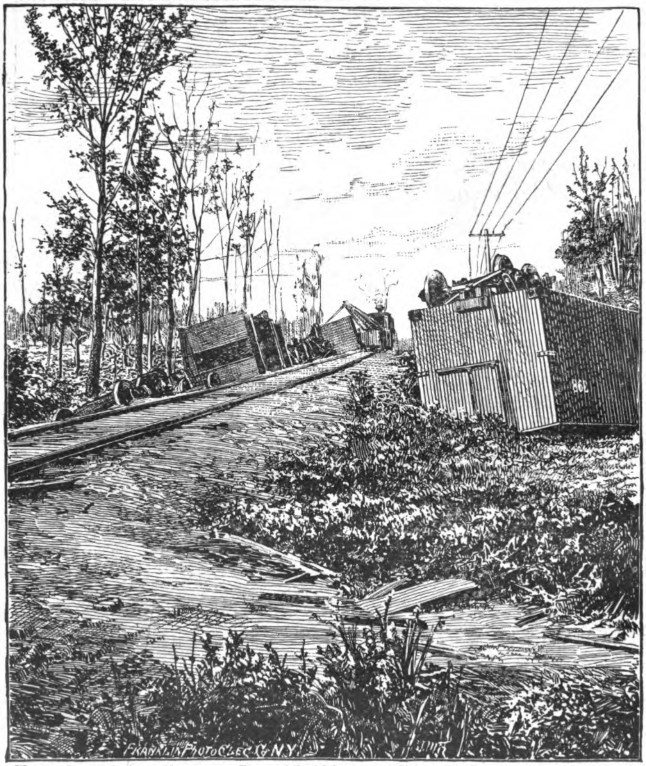
bolts, were broken asunder as if they had been pipe-stems. The iron portion of the bridge consisted of two spans of 125 feet each, and four chords with a rise each of 18 feet, weighing twenty-seven tons to the chord. Several of the large iron



Tornado at Grinnell, Iowa, June 17, 1882. Portion of train on Iowa Central, east of track. From a Photograph.

rods, 2½ inches in diameter, sticking out of the water upon the sandy beach were found broken square in two; smaller ones, and broad, flat strips of iron were twisted into fantastic shapes.

So easily and yet so completely was the great structure lifted from its foundation that but two of the top stones were moved from the eastern pier. This was perhaps the most terrific manifestation of force ever exhibited by any storm in



Tornado at Grinnell, Iowa, June 17, 1882. Portion of train on Iowa Central west of track. From a Photograph.

this section of country. The structure was practically new, having been built but a few years before at a cost of $20,000. The cloud from this point passed up the river, following the bends to the north and northwest for a distance of about

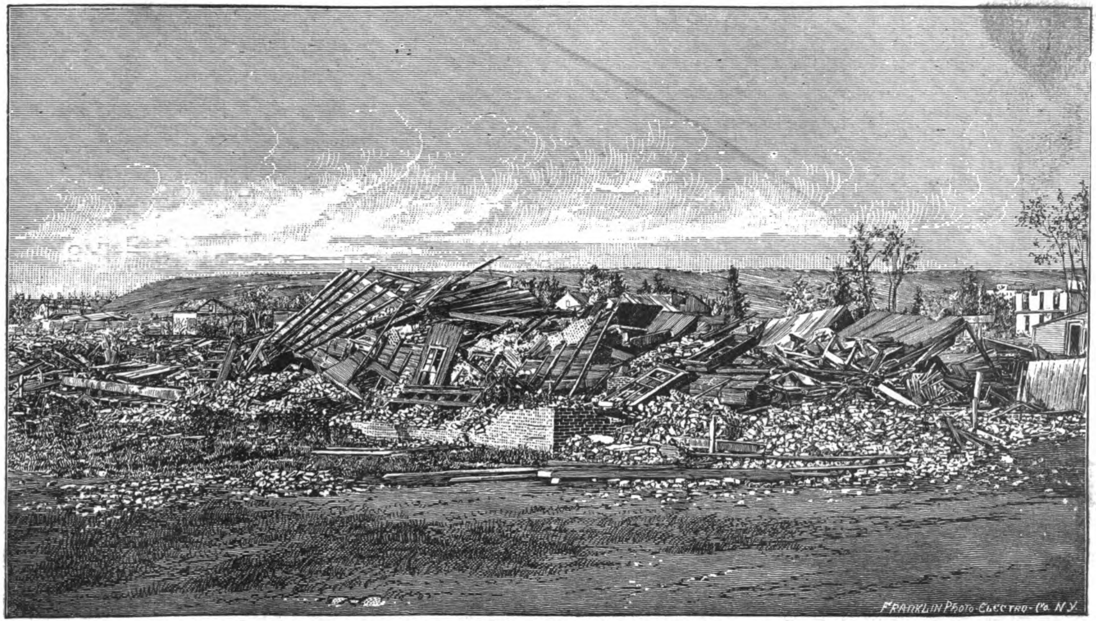
1,200 feet, when it reached a small 'draw' from 250 to 300 feet wide, cutting up through the bluffs to the east and reaching the high prairie beyond. Up this opening the cloud ascended with terrible fury, uprooting and breaking off large oaks and hickories 18 inches to three feet in diameter, and plowing up the earth in deep furrows. While passing up the river the water was subjected to the extraordinary violence of the whirling currents of air and forced backward on either side to the banks, exposing to view the bed of the stream for a considerable distance. The violent uprush of the air in the center of the cloud carried the water in spray above the tops of the highest trees."

A further description of this storm, in the vicinity of Irving, Kansas, presents a thrilling account of the terrible devastation wrought by it. A heavy westerly wind, causing considerable damage, prevailed at Waterville and Blue Springs, eight miles to the northwest. This current passed eastward to Irving, reaching the town after the first storm had disappeared on the high prairie beyond the river. In the wake of the first tornado a warm southerly wind passed over the town accompanied by rain. The sun, now partially exposed beneath the heavy clouds lining the western horizon, threw its warm rays upon the terror-stricken inhabitants, who, at this welcome invitation, assuring them as they thought of peace and protection, emerged from their cellars and dug-outs to witness the destruction already committed and relieve their suffering neighbors. Hardly had the people recovered from the first shock, when there appeared in the West a cloud of inky blackness and enormous dimensions, presenting a square front of apparently two miles in width and a perpendicular height from earth to sky. It moved along slowly, but with the most inconceivable majesty of force, annihilating everything within its reach. The cloud is now at the outskirts of the town, and as it begins to execute its frightful mission of death and destruction the earth fairly

quakes and trembles. All nature stands aghast, and every living thing seeks, but in vain, to find security from the impending danger. Many people actually believe that the Judgment Day has come, and offer fervent prayers and loud appeals for preservation. But the hand of mercy stays not the dreadful carnage. It begins. The awful roar, like the belchings forth of a thousand Columbiads, drowns the most piercing cries of the wounded. The cloud strikes into a cluster of eighteen houses and other buildings filled with human beings and the accumulations of years.

In an instant everything is swept from the earth in terrible ruin. Death is experienced in its most dreadful forms. At the house of a Mr. Keeney, the father, mother, and grandfather were blown two hundred yards to the northeast, where they were found lying within a few feet of each other mangled and dead. Mrs. Keeney was dashed head foremost into the soft ground up to her shoulders, entirely stripped of her clothing, and covered with black mud. The other two were partially stripped of their garments and also covered with mud, which was fairly beaten into their clothes. The three children of this family were carried by the wind several hundred yards, stripped of their clothing, their bodies covered with mud, but they were not killed.

The house of a Mr. Sheldon was crushed to the earth and portions of the débris carried for miles in the air. A daughter, twenty-two years of age, was blown to the southeast a distance of two hundred yards, into a low, wet piece of ground. Nearly every bone in her body was broken, and the flesh in many places terribly lacerated by flying débris. The body was found in a perfectly nude condition and almost unrecognizable, because of the grass and mire beaten into it. Mr. Leddy's house was surrounded by a grove of cottonwood trees and a picket fence. The building was lifted bodily above the tops of the highest trees and dashed to pieces upon the earth. The east and south fencing was car-



Tornado at Rochester, Minn., Aug. 21, 1883. Ruins of a Machine Shop. From a Photograph.

ried away, and those of the trees left standing were stripped of every portion of bark and foliage and most of the limbs. Wound about their trunks and fluttering from the bare limbs were fragment of garments, strips of long prairie grass and scraps of paper. On that portion of the picket fence not destroyed, there hung shreds of every article of clothing common to the household; and within a radius of thirty to forty rods lay portions of chairs, sofas, bedsteads, stoves, tins, and crockery-ware, mingled with shingles, lath, shedding, clap-boards, sills, doors, window-frames, etc. The utter desolation was dreadful to behold. A few moments before, health, happiness, and plenty made these homes the scene of comfort, where now grim death and absolute waste reigned supreme.

The effect upon those who were left to mourn the tragical death of friends and relations was pitiful in the extreme. This prosperous community had been scourged by a fell destroyer more dreadful than either flood or fire, epidemic or war. It came in the twinkling of an eye and all was gone; life, property, happiness crushed and annihilated; swept with lightning speed into eternity. The little graveyard was dotted with many fresh mounds. The power of the tornado-cloud for a few moments had sufficed to accomplish what disease and accident had not done in years. The terrible storms of May 29th and 30th, 1879, will never be forgotten in the States of Kansas, Missouri, Iowa, and Nebraska. Night after night following the storms, hundreds of people never went to bed; but, with lanterns trimmed, peered into the darkness watching for a recurrence of the dreadful scenes through which they had just passed. Every dark cloud or sudden freshening of the wind filled them with evil forebodings which could not be allayed until every vestige of supposed danger had vanished. The terror depicted upon the countenances of the bravest men at the sight of a dark cloud, though it might be perfectly harmless, was something beyond

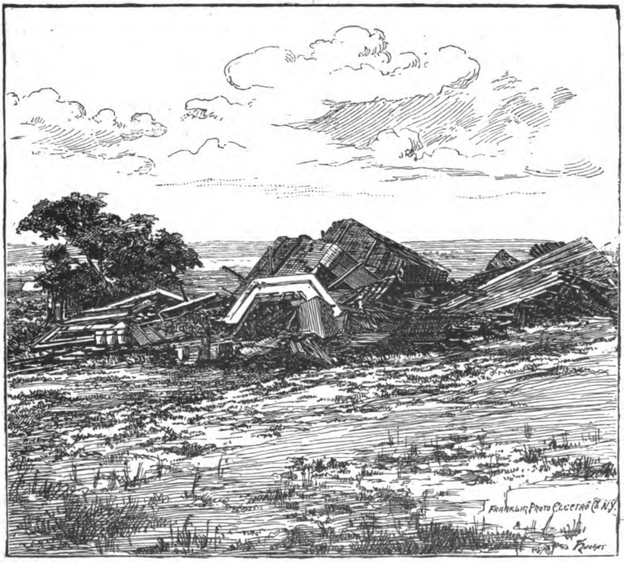
description or realization, except by those who could witness their excitement. Persons were preparing to quit the country; business of every kind succumbed for a season except that of generously supplying the wants of the sufferers by well-organized relief committees. Many acts of self-sacrifice and devotion redound to the glory and honor of Kansas people.

THE SOUTH CAROLINA TORNADO OF APRIL 16TH, 1879.

The following information relates to the tornado of April 16th, 1879, near Walterborough, South Carolina. The data are taken from the Chief Signal Officer's report for 1879.

VELOCITY AND FORCE OF THE WIND IN THE CLOUD VORTEX.

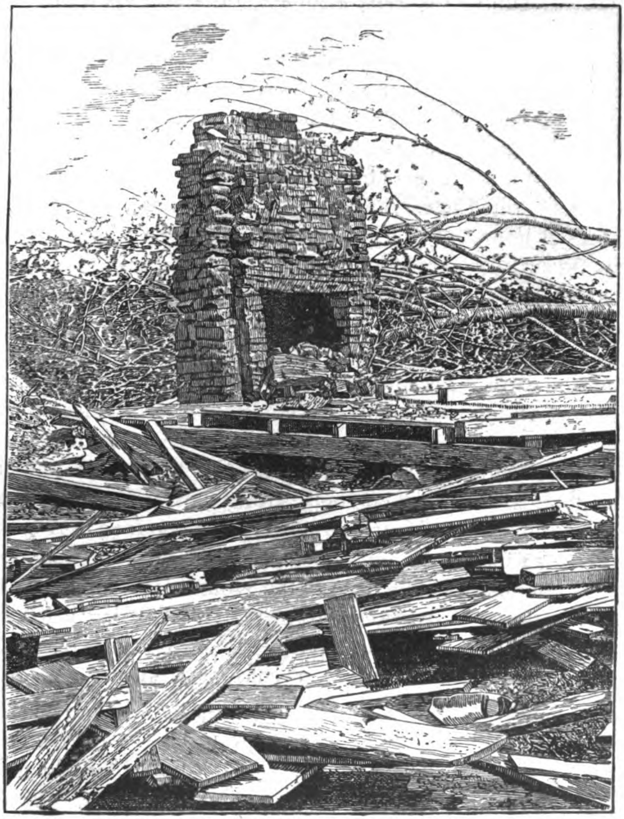
A pigeon-house exposing 24 square feet of surface to the action of the wind, and weighing 1,000 pounds, was carried



Tornado at Kansas City, July 17, 1880. Mr. Post's house, 19th and Mercer Sts. From a Photograph.

80 feet and demolished against a house. By adding to this one-third of its weight for friction, the least possible wind velocity required to move it is 105 miles per hour. It may have been twice that velocity.—A one-story house exposing 200 square feet to the wind and weighing 15,000 pounds was carried a distance of six feet. Least required velocity, 142 miles per hour.—A church exposing a surface of 1,000 square feet to the wind and weighing 50,000 pounds was carried 20 feet from its foundation and demolished. Velocity required, 116 miles per hour.—A house exposing 360 square feet of surface and weighing 25,000 pounds was moved 20 feet from its foundation. Least required velocity, 136 miles per hour.—A storeroom weighing 10,000 pounds and exposing 128 square feet of surface, tilted to an angle of 45°. Velocity required, 144 miles per hour.—A piece of timber weighing 600 pounds, its greatest surface exposed to the wind being 20 square feet, was carried 440 yards. Least velocity required, 90 miles per hour.—A buggy weighing 150 pounds was carried up in the whirl, and the pieces hung on a tree at the height of 60 feet from the earth. Distance carried, 300 feet.—Two panels of fence weighing 150 pounds were carried a distance of 300 feet.—A weather-board was found to have been carried a distance of six miles, it being recognized by the paint; weight, six pounds.—A chicken-coop, strong box, 4 by 4 feet, was carried a distance of four miles; weight, 75 pounds.—A hickory tree 54 inches in circumference at butt, and weighing 3,000 pounds, was lifted out of the ground and moved up a bank ten feet.—A cart weighing 600 pounds was carried up in the whirl, torn to pieces, and the tire of one wheel found 1,320 yards distant.—An iron chisel weighing four pounds was carried 90 feet, and driven into a piece of pine timber a distance of 2 inches.—Two large hubs of a road-wagon, without spokes, but attached to an iron axle, and weighing 175 pounds, were carried a distance of 750 feet.—A basket of books weighing 50 pounds was carried a distance of 2½

miles, and found hanging on a tree with the contents intact.—A cart weighing 400 pounds was carried a distance of 125 feet and demolished.—Geraniums in pots were found by the owner one mile from town uninjured.—A buggy left at a shop near the center of the town to be repaired, could never be found.—Letters and books were carried a distance of 6 miles.



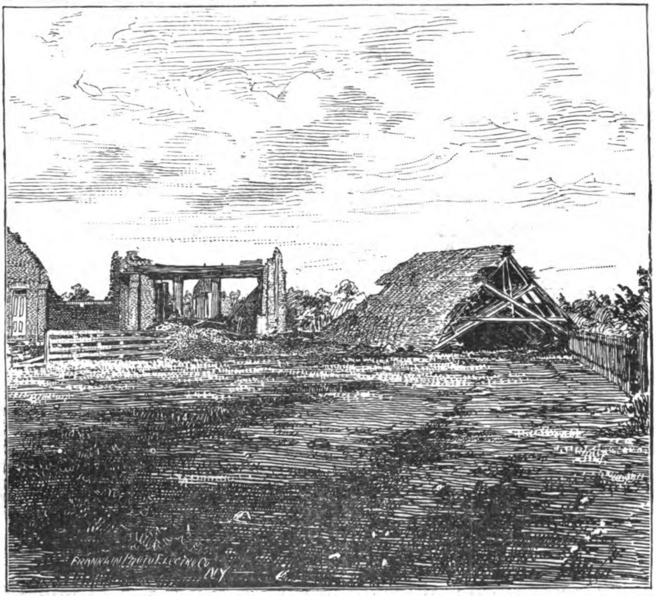
Tornado at Auburn, Ala., April 15, 1884. Ruins of a dwelling. From a Photograph.

Pieces of matting and dresses were found 10 miles away. Dead sheep were found shorn of their wool to the bare skin, by the force of the wind.—Fowls were plucked of their feathers as if picked by hand.—Birds were killed, and none were seen in the neighborhood for several days after the storm.

Tornado at Racine, Wis., May 18, 1883. House twisted from its foundation. From a Photograph.

On February 19th, 1884, the States of Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Tennessee, and Kentucky were visited with the most terrible devastation by wind ever experienced in this country. From 10 o'clock in the morning until 12 midnight sixty tornadoes occurred in different parts of the above-named States. Rough estimates placed the loss of property at from $3,000,000 to

$4,000,000; the loss of life at 800, and the number of wounded at 2,500. The number of people rendered homeless and destitute numbered from 10,000 to 15,000, many of whom were left in a starving condition. The number of buildings destroyed was about 10,000. Cattle, horses, hogs, and other domestic animals were destroyed in great numbers.



Tornado at Springfield, Mo., April 18, 1880. Ruins of Catholic church.
From a Photograph.

The tale of distress, ruin, and death might be readily augmented by reciting the horrors of the Grinnell tornado, which desolated a large section of central Iowa on the afternoon and night of June 17th, 1882. The town of Grinnell, with its fine college buildings, was nearly swept from the earth, and 130 human souls dashed into eternity in less time than it takes to relate it.

The great tornadoes of April 18th, 1880, in southwestern Missouri, destroying the town of Marshfield, and killing over 100 people.

The tornadoes of August 3d, 1885, in Maryland, Delaware, New Jersey, and Pennsylvania, destroying over two millions worth of property and many lives.

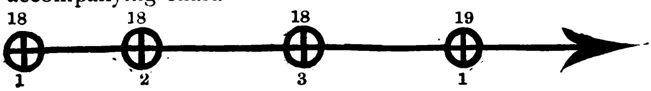
The tornadoes of April 14th, 1886, in Minnesota, destroying the towns of Saint Cloud and Sauk Rapids, with a loss of over $500,000 and nearly 100 lives.

Each year swells the record of death and destruction, and makes the contemplation of these dreadful events, which occur with so much certainty and regularity, a source of the deepest concern to those who live in the tornado districts; and, naturally, turns the mind towards the means for the preservation of life and indemnification for property loss.

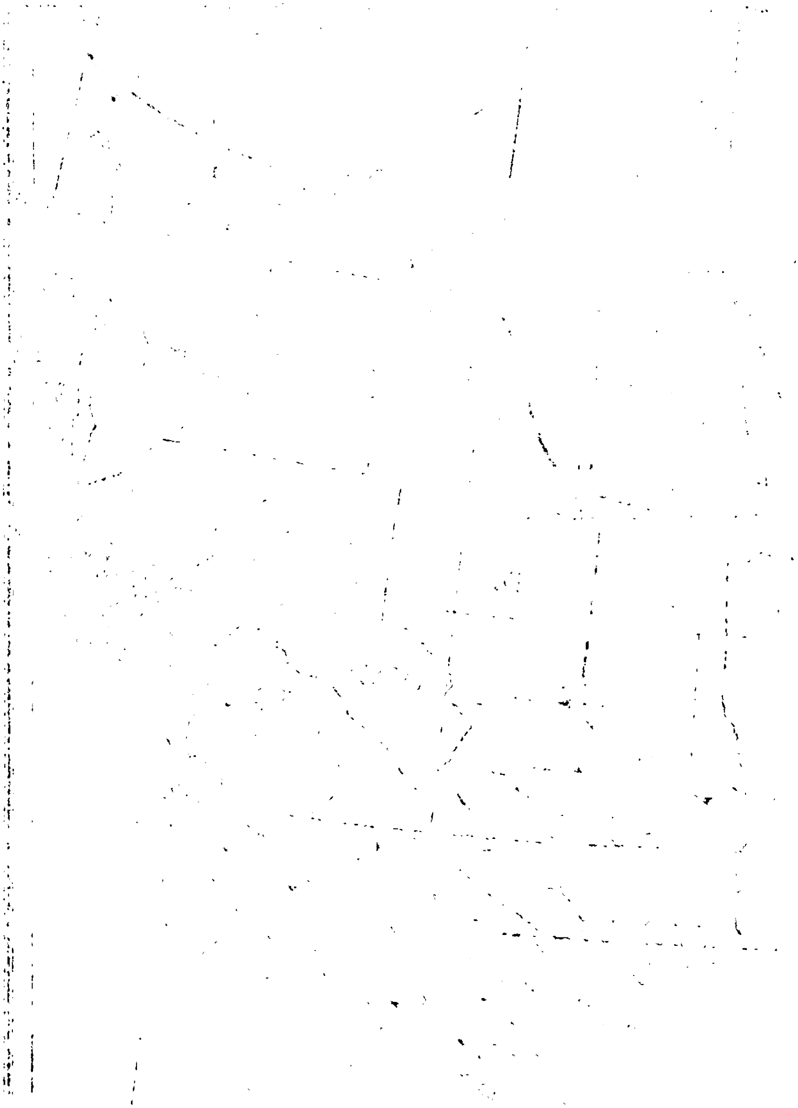
CHART NO. 2.

Chart No. 2 refers to the very remarkable tornadoes of February 19th, 1884.

On the upper portion of the chart there is delineated the course of progressive movement of the main storm-center, or the central area of barometric minimum. By this is meant the path pursued by the general storm which prevailed over the northern portion of the United States on the day above indicated. It is usual to represent the direction of movement of the center of a great storm by a line. In the cartographical study of storms by the Signal Service the position of the center is described at three distinct times during the 24 hours, viz.: At 7 A. M., 3 P. M., and 10 P. M. To illustrate the direction of movement and the day and hour of observation, the following symbol is used, similar to that shown on the accompanying chart.



The upper figures indicate the day of the month, and the



lower figures show the hour of observation. 1 is equivalent to 7 A. M., 2 to 3 P. M., and 3 to 10 P. M. The track of the general storm is shown for the 18th, 19th, and 20th. On the lower portion of Chart No. 2 is shown the position and direction of movement of the various tornadoes that occurred on the 19th of February, 1884. The tracks are indicated by the following symbol: XXXXXX——————→

The principal object of this chart is to show that a definite relation exists between the location of the center of the general storm and the place of tornado action and development. It is now established beyond question that no tornadic action ever takes place without the presence (always north and west of the tornado region) of a general storm or "low," as it is technically called, and that, too, of marked intensity and peculiar form. Now, it is of great practical importance for the public to bear this fact in mind when they are watching the daily bulletins and weather indications of the Signal Service, which are published broadcast throughout the country. Whenever a general storm is known to be moving eastward over the United States in the season of year favorable for tornadoes, the following deductions, which have resulted from a long and careful consideration of the subject, should be thoughtfully studied and clearly understood.

1. There is a definite portion of an area of low pressure within which the conditions for the development of tornadoes are most favorable, and this is called the dangerous octant.

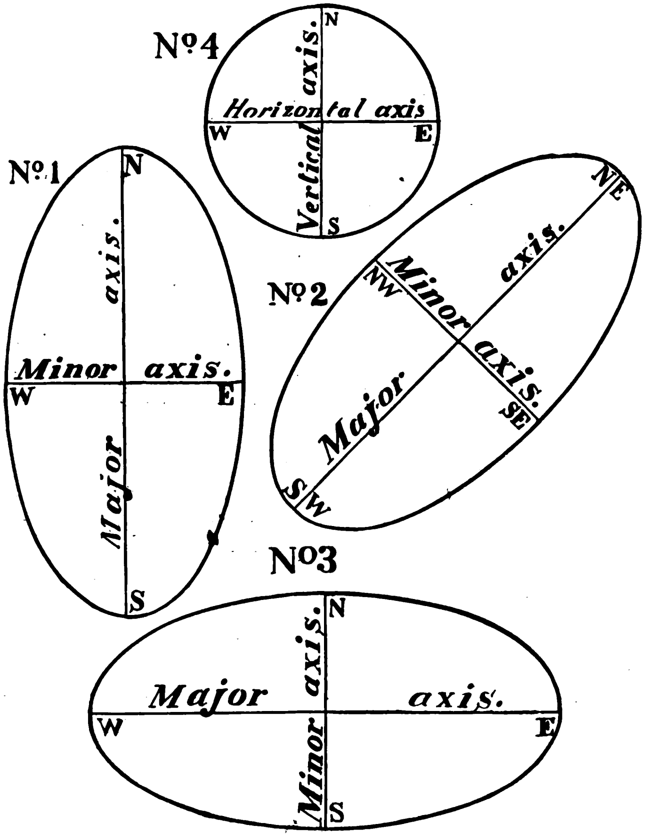
2. There is a definite relation between the position of tornado regions and the regions of high contrasts in temperature (temperature gradient), the former lying to the south and east.

3. There is a similar definite relation of position of tornado regions and the region of high contrasts in dew-points, the former being as before to the south and east.

4. The position of tornado regions, or the area of tornadic action, is to the south and east of the region of high contrasts

of cool northerly and warm southerly winds—a rule that seems to follow from the preceding, and is of use when observations of temperature and dew-point are not accessible.

5. The relation of tornado regions to the movement of upper and lower clouds shows that the former indicate the presence of the cold northwest current, and the latter the warm southwest current of air, which ultimately lead to the



development of the high contrasts of temperature so essential to the birth of tornadic action.

6. The study of the relations of tornado regions to the form of barometric depressions shows that tornadoes are more frequent when the major axis of the barometric trough trends north and south or northeast and southwest, than when it trends east and west.

ILLUSTRATION. SEE OPPOSITE PAGE.

The forms of barometric depression, as shown in diagrams Nos. 1 and 2, are favorable to tornado development; those shown in diagrams Nos. 3 and 4 are unfavorable to such development. These facts should be carefully considered when examination is made of the storm conditions as shown on the daily weather-map of the Signal Service, which is now displayed in all of the principal cities of the country and is placed in the hands of many private subscribers.

The following table, prepared by Prof. H. A. Hazen, of the Signal Service, presents very interesting and valuable information concerning the relation of the region of tornadic action to the position and intensity of the area of barometric minimum or general storm-center.

The general average of this table gives the mean distance of tornadic action from the "low," or storm-center, as 453 miles. The mean direction is south 39° east. The mean temperature fall is ten degrees in 259 miles. The winds are almost uniformly from the south and southeast, and if from any other quarter, all are from that direction. The distances to the nearest north winds are variable, and in many instances there were no north winds on the map near the "low" or near the tornado. The mean distance of north winds in thirty-one cases was 407 miles.

Table.

Place.	Lat.	Long.	Date. Hour.	Distance (miles) to and direction from low center.	Temperature falls 10° in miles.	Winds near Tornado.	Distance to nearest N. Wind.	Pressure at low center, inches.
Charlotte, N. C.	35·2°	80·8°	Sept. 8, '72, 5 p.m.	650 S.E. 135°	500	S. & S.E.	650	29·76
Keokuk & Washington Co's, Ia.	41·3*	92·0*	May 22, '73, 2.15 p.m.	440 S.E. 135	200	S. & S.E.	370	29·28
Cloud Co., Kans.	39·6	97·7	June 29, '73, 3 p.m.	480 S.S.E. 158	520	S. to E.	520	29·60
Cairo, Ills.	37·0	89·2	Mar. 18, '74, 4 a.m.	370 E.S.E. 112	210	S. & S.E.	260	29·76
DeSoto Co., La.	32·0	93·6	Apr. 7, '74, 4 p.m.	260 E.S.E. 112	140	S.E.	220	29·70
Butler Co., Kans.	37·8	96·9	June 22, '74, p.m.	660 S.S.E. 158	400	S. & S.E.	none†	29·44
Troy, N. Y.	42·7	73·6	Aug. 2, '74, p.m.	580 S.S.W. 202	260	N. & N.W.	......	29·55
Dixon, Ills.	41·8	89·5	Aug. 10, '74, p.m.	620 S.E. 135	200	S.W. to S. E.	none†	29·33
Montevallo, Ala.	33·1	86·9	Nov. 22, '74, p.m.	490 S.E. 135	130	S.	670	29·04
Fulton, Miss.	34·2	88·3	May 1, '75, p.m.	600 S.S.W. 202	120	N.W.	......	29·10
St. Joseph Co., Ind.	41·6	86·3	June 1, '75, p.m.	610 S.E. 135	150	S. to E.	none†	29·31
Quincy, Ills.	39·9	91·4	June 14, '75, p.m.	540 E.S.E 112	110	S.W. to S. E.	350	29·41
Omaha, Nebr.	41·3	95·9	June 17, '75, p.m.	270 S.E. 135	160	N.E.	......	29·60
West Point, N. Y.	41·3	74·0	July 13, '75, 7.10 p.m.	420 S. 180	150	S.W.	390	29·54
Salem Co., N. J.	39·5	75·3	July 29, '75, 3 p.m.	550 S.E. 135	100	S.W. & S.	290	29·72
Lomonauk, Ills.	41·6	88·7	Aug. 5, '75, 7.20 p.m.	210 S.E. 135	390	S. & S.W.	410	29·50
Milford, Pa.	41·3	74·8	Oct. 30, '75, p.m.	350 S.E. 135	270	S. & S.W.	800	29·53
Chicago, Ills.	41·9	87·6	Apr. 26, '76, 5.10 p.m.	780 S.E. 135	210	S. & S.W.	none†	29·41
Carbondale, St. Clair Co., Ills.	37·8	89·2	May 6, '76, 9.30 p.m.	360 S.S.E. 158	240	S. & S.E.	200	29·41
Saline Co., Kans.	38·8	97·7	June 6, '76, 3.30 p.m.	480 S.S.E. 158	400	S.W. to S. E.	600	29·45

* Lat. and long. of center   † No north wind.

TABLE.—CONTINUED.

Place.	Lat.	Long.	Date. Hour.	Distance (miles) to and direction from low center.			Temperature falls 10° in miles.	Winds near Tornado.	Distance to nearest N. Wind.	Pressure at low center, inches.
Washington Co., N. Y.	43·2°	73·2°	May 18, '77, 1.30 p.m.	220	S.S.W.	302°	200	S. & S.W.	400	29·59
Memphis, Tenn.	35·1	90·0	June 17, '77, 7 p.m.	1040	S.E.	135	1000	S. & S.E.	650	29·28
Elkhart, Ind.	41·7	86·0	July 2, '77, 4.30 p.m.	1030	S.E.	135	200	S. & S.E.	580	29·58
Council Bluffs, Ia.	41·3	95·6	Aug. 6, '77, 2.30 p.m.	520	S.S.E.	158	580	S. & S.E.	190	29·75
Fayetteville, N. C.	35·0	78·9	Feb. 8, '78, 7 a.m.	420	S.E.	135	420	S. & S.W.	430	29·30
Cairo, Ills.	57·0	89·2	Apr. 23, '78, 4.10 a.m.	400	S.S.E.	158	240	S.E.	350	29·43
Carolina Landing, Miss.	33·0	91·1	May 18, '78, p.m.	720	S.E.	135	120	S.	490	29·28
Barrington, Ills.	42·2	88·1	May 23, '78, 6 p.m.	600	S.E.	135	130	S.W. to S.E.	340	29·32
Cash Co., Mo.	38·6	94·3	July 16, '78, 2 p.m.	420	S.	180	700	S.	350	29·54
South Hartford, N. Y.	43·3	73·2	July 26, '78, 5.30 p.m.	290	N.E.	45	90	S. & S. W.	270	29·29
Wallingford, Conn.	41·5	72·9	Aug. 9, '78, 6 p.m.	480	S.	180	150	S. & S. W.	300	29·40
Near Dover Mines, Va.	37·7	77·9	Sept. 12, '78, 4 p.m.	300	N.E.	45	160	E. & S. E.	300	29·48
Monticello, Jones Co., Ia.	42·2	91·2	Oct. 8, '78, 5.30 p.m.	320	E.N.E.	68	90	S. & S. W.	260	29·54
Collinsville, Ills.	38·7	90·0	Apr. 14, '79, 2.45 p.m.	160	S.S.W.	202	100	N. & N. E.	......	29·50
Dallas, Tex.	32·8	96·8	Apr. 15, '79, 2 p.m.	240	S.E.	135	100	E. & N. E.	......	29·34
Walterboro, S. C.	32·9	80·7	Apr. 16, '79, 3.45 p.m.	320	S.E.	135	210	S. & S. E.	420	29·47
Barnard, Mo.	40·2	94·8	May 29, '79, 3.30 p.m.	420	S.	180	300	S.W. & S.	600	29·29
Lees Summit, Mo.	38·9	94·3	May 30, '79, 5.30 p.m.	260	E.	90	240	S. E. & S.	330	29·40
Delphos, Kans.	39·3	97·8	May 30, '79, 4 p.m.	60	E.N.E.	68	150	N. & N.W.	......	29·40
Erie Co., O.	41·4	82·7	July 11, '79, 3 p.m.	230	S.W.	225	300	S. & S.W.	300	29·46
Sandy Spring, Ind.	39·2	77·0	Sept. 3, '79, 6 p.m.	420	S.E.	135	270	S. & S.W.	510	29·33
Means.	......	......	......	453	S. 39° E.	141	259	......	......	29·45

LIST OF TABLES GIVING CONDENSED INFORMATIONS CONCERNING TORNADOES; GEOGRAPHICAL, FINANCIAL, CHRONOLOGICAL, DESCRIPTIVE, ETC.

The following tabulations present in a comprehensive and concise manner the very foundation upon which the superstructure of this work has been reared.

Tornado study as submitted in these pages was pursued by inductive methods. Investigation was made in the field, subject to all the inclemencies of the weather.

The tornado's peculiar formation and dreadful violence were carefully observed and actually experienced, no effort or sacrifice being spared to secure the unvarnished facts without predisposition to any theory.

We have then as the outcome of such methods of study, a compendious summary of tornado observation and research, which has been conducted unremittingly for the past ten years and which will form the ground-work of all future investigation into this class of meteorological phenomena.

The data used in these tables are matters of official record, but their presentation and arrangement conform to the ideas of the author and exhibit a classification which it is thought will best serve for the information of those interested.

Table No. 1.

A table showing the total number of Tornadoes observed in the United States during a period of 205 years, from 1682 to 1886, inclusive.

STATES AND TERRITORIES.	No. of Storms.	STATES AND TERRITORIES.	No. of Storms.
Missouri,	156	Arkansas,	34
Kansas,	153	Tennessee,	31
Georgia,	128	Kentucky,	26
Illinois,	127	Massachusetts,	22
Iowa,	118	Louisiana,	19
Alabama,	102	Virginia,	18
Ohio,	92	Maryland,	16
Indiana,	84	Connecticut,	13
Minnesota,	78	New Jersey,	12
Texas,	73	Florida,	10
Michigan,	71	New Hampshire,	8
New York,	67	Maine,	7
Pennsylvania,	61	Indian Territory,	6
Wisconsin,	59	Vermont,	4
North Carolina,	59	Colorado,	4
South Carolina,	57	West Virginia,	2
Nebraska,	52	Rhode Island,	1
Mississippi,	49	Delaware,	1
Dakota,	46	District of Columbia,	1

Total number observed, ... 1,867

Table No. 2.

The Violence of Tornadoes expressed relatively by States in the order named. By violent in this sense is meant the most completely developed storms, with perfect conditions longest sustained.

STATES.	STATES.	STATES.	STATES.
Missouri,	Dakota,	Pennsylvania,	Vermont,
Iowa,	Kansas,	Kentucky,	Maryland,
Alabama,	Illinois,	Tennessee,	New Hampshire,
Arkansas,	Nebraska,	Virginia,	Maine,
Georgia,	Ohio,	Massachusetts,	Rhode Island,
South Carolina,	Indiana,	Indian Territory,	Delaware,
Wisconsin,	Mississippi,	New Jersey,	Colorado,
Minnesota,	Texas,	Louisiana,	Florida,
North Carolina,	New York,	Connecticut,	West Virginia.
Michigan,			

Table No. 3.

Violence of Tornadoes by States, embracing the destruction of property, reported indefinitely as "much," "great." etc.; loss of life, reported definitely and indefinitely; and number of people wounded, reported definitely and indefinitely.

STATES.	DESTRUCTION OF PROPERTY.				LIVES LOST.				PERSONS INJURED.		
	"Very destructive," No. of cases.	"Much property," No. of cases.	"Town destroyed," No. of cases.	"Destruction great," No. of cases.	Definite No. reported.	"Many," No. of cases.	"Several," No. of cases.	"Hundreds" No. of cases.	Definite No. reported.	"Many," No. of cases.	"Several," No. of cases.
Alabama,	6	28	..	..	68	1	3	..	117	5	6
Arkansas,	2	7	..	..	29	..	..	..	229	..	4
Connecticut,	3	..	..	..	34	..	..	..	48	..	1
Dakota Ter.,	7	6	..	..	29	..	..	..	42	..	1
Delaware,	..	..	..	..	..	..	..	..	..	..	..
Florida,	1	2	..	..	6	..	1	..	6	..	..
Georgia,	7	30	..	..	150	2	7	..	192	..	6
Illinois,	19	23	6	..	368	1	1	..	161	3	9
Indiana,	4	21	..	..	39	..	2	..	35	1	6
Indian Ter.,	1	1	1	..	21	..	1	..	43	1	..
Iowa,	15	34	..	..	175	..	4	..	424	2	6
Kansas,	27	23	..	..	76	..	2	..	204	4	4
Kentucky,	4	7	..	..	46	..	..	..	107	1	1
Louisiana,	..	5	..	..	12	..	..	..	55	1	1
Maryland,	2	2	..	..	..	..	..	..	4	..	..
Mass.,	2	2	..	..	3	..	..	..	8	..	..
Michigan,	14	17	..	..	34	..	1	..	70	..	4
Minnesota,	13	12	..	..	164	..	1	..	567	1	4
Mississippi,	5	11	1	..	935	..	3	..	471	..	3
Missouri,	22	28	1	..	247	1	5	..	1050	5	4
Nebraska,	5	14	..	.	14	..	..	..	31	..	..
New Hamp.,	1	4	..	..	7	..	..	..	..	1	..
New Jersey,	..	1	..	..	9	..	..	..	111	..	..
New York,	14	13	..	..	15	..	..	..	29	1	3
N. Carolina,	5	17	..	..	30	1	3	1	142	1	4
Ohio,	18	16	1	..	154	3	..	..	252	4	11
Penn.,	7	14	1	1	142	2	2	..	23	2	3
Rhode I'ld.,	..	1	..	..	..	..	..	..	..	..	..
S. Carolina,	2	13	..	..	104	..	1	..	91	1	5
Tennessee,	1	5	..	..	11	..	..	..	9	1	1
Texas,	18	12	..	..	102	..	2	..	146	3	6
Vermont,	..	..	..	..	..	..	..	..	..	..	..
Virginia,	2	1	..	..	..	..	1	..	..	1	..
Wisconsin,	6	14	1	..	141	1	2	..	382	1	2
TOTALS,	233	384	12	1	3165	12	42	1	5049	40	95

Note.—This table is only approximate in its values, for in many cases of Tornado occurrence no reports could be obtained as to loss of life and injury to persons and property. "Destruction of property" referred to in this table is entirely independent of the money value given in table No. 5.

Table No. 4.

ACTUAL YEARS OF TORNADO RECORDS REPRESENTED IN THE CHARTS AND TABLES.

1682	1804	1818	1830	1840	1850	1860	1869	1878
1728	1805	1819	1831	1841	1851	1861	1870	1879
1729	1807	1820	1832	1842	1852	1862	1871	1880
1761	1808	1821	1833	1843	1853	1863	1872	1881
1787	1809	1822	1834	1844	1854	1864	1873	1882
1788	1810	1823	1835	1845	1855	1865	1874	1883
1791	1811	1824	1836	1846	1856	1866	1875	1884
1794	1814	1826	1837	1847	1857	1867	1876	1885
1795	1815	1827	1838	1848	1858	1868	1877	1886
1797	1816	1829	1839	1849	1859			

Total number of years, EIGHTY-SEVEN.

Length of Period (1682-1886), TWO HUNDRED AND FIVE YEARS.

The Tornado for 1682 occurred at New Haven, Conn., June 10, at 2 30 P. M. and was exceedingly destructive.

Table No. 5.

TIME OF TORNADO DEVELOPMENT WITH RESPECT TO REGION OF COUNTRY.

AVERAGE RESULTS.

In considering this question the application of the rule is made in a general sense, and a somewhat arbitrary geographical distribution of time over that section of the United States east of the Rocky Mountains is made. There are four periods of time, and therefore four separate regions of tornadic action, which are described as follows :—

FIRST PERIOD.—December to March, inclusive, comprising the region embraced by the following States: Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, and Southern Kentucky.

SECOND PERIOD.—April to June, inclusive. Region: Texas, Louisiana, Arkansas, Missouri, Kansas, Colorado, Iowa, Nebraska, Dakota, and Minnesota.

THIRD PERIOD.—June to August, inclusive. Region: Wisconsin, Michigan, Illinois, Indiana, Ohio, Northern Kentucky, Western Pennsylvania, Western New York, and West Virginia.

FOURTH PERIOD.—August to November, inclusive. Region: Maryland, Delaware, New Jersey, Eastern Pennsylvania, Eastern New York, and the New England States.

Table No. 6.

TORNADO RECORD OF THE SEVENTEEN YEARS LAST PAST.

Year.	Storms. Observed.	Year.	Storms. Observed.
1870	9	1879	89
1871	9	1880	137
1872	13	1881	114
1873	12	1882	88
1874	21	1883	161
1875	80	1884	200
1876	66	1885	136
1877	70	1886	280
1878	81		

Total number in seventeen years, 1566.

A comparison of the data presented in this table with that shown in Nos. 1 and 8, reveals the fact that over 80 per cent of the observed tornadoes belong to less than 9 per cent of the length of period. This fact, combined with a cursory review of table No. 12, might lead one to the conclusion that tornadoes were on the increase. This would certainly be erroneous, and for the following reasons:

1st. A careful study of tornado development and distribution, shows that there are as many considerations to justify the belief that tornadoes were quite as frequent a hundred years ago as now, and that this degree or frequency will not be diminished for a hundred years to come.

2d. The means of observation and record for 1886 surpassed those of any other year, because the Signal Service had greater facilities for collecting reports, and the rapid growth of the country, with a greater zeal of the press, brought to light many occurrences which, before, would have been lost sight of.

3d. A study of tornado development and distribution appears to indicate that there are periods of maximum occurrence, alternating with those of minimum occurrence, but the truth of the supposition remains yet to be determined, when more complete and extended records are obtainable.

4th. Tornado records are not yet sufficiently full and complete to permit the deduction that they are or are not on the increase.

5th. The conditions, atmospheric, topographical, and geographical, under which tornadoes are peculiar to the United States, or certain sections of it, have remained the same for ages, and there is no likelihood of a change in this direction to prevent or increase the occurrence of tornadoes.

Table No. 7

Time of Occurrence of Tornadoes, to show the Hour and Portion of Day of Greatest Frequency.

TIME.	No. of Cases,	TIME.	No. of Cases.	TIME	No. of Cases.	No. of Cases, time not recorded.	Total No. of Storms observed.
12 m. to 12.30 a.m.	5	12.00 m. to 12.30 p.m.	13	Bet. 8.00 a.m. & 10.00 a.m.	1		
12.30 a.m. to 1.00 a.m.	5	12.30 p.m. to 1.00 "	26	" 4.30 p.m. & 6.10 p.m.	1		
1.00 " " 1.30 "	4	1.00 " " 1.30 "	21	"Daylight."	2		
1.30 " " 2.00 "	7	1.30 " " 2.00 "	48				
2.00 " " 2.30 "	3	2.00 " " 2.30 "	25	"a.m."	3		
2.30 " " 3.00 "	5	2.30 " " 3.00 "	59				
3.00 " " 3.30 "	8	3.00 " " 3.30 "	44	"Early Morning."	1		
3.30 " " 4.00 "	2	3.30 " " 4.00 "	129				
4.00 " " 4.30 "	2	4.00 " " 4.30 "	62	"Morning."	6		
4.30 " " 5.00 "	2	4.30 " " 5.00 "	123				
5.00 " " 5.30 "	2	5.00 " " 5.30 "	60	"About Noon."	4		
5.30 " " 6.00 "	5	5.30 " " 6.00 "	95				
6.00 " " 6.30 "	1	6.00 " " 6.30 "	41	"p.m."	20		
6.30 " " 7.00 "	5	6.30 " " 7.00 "	56				
7.00 " " 7.30 "	2	7.00 " " 7.30 "	31	"Afternoon."	255		
7.30 " " 8.00 "	4	7.30 " " 8.00 "	39				
8.00 " " 8.30 "	1	8.00 " " 8.30 "	25	"Sundown."	2		
8.30 " " 9.00 "	2	8.30 " " 9.00 "	32				
9.00 " " 9.30 "	4	9.00 " " 9.30 "	17	"Evening."	38		
9.30 " " 10.00 "	11	9.30 " " 10.00 "	24				
10.00 " " 10.30 "	3	10.00 " " 10.30 "	15	"Night."	27		
10.30 " " 11.00 "	14	10.30 " " 11.00 "	22				
11.00 " " 11.30 "	12	11.00 " " 11.30 "	14				
11.30 " " 12.00 "	34	11.30 " " 12.00 mid	18				
Totals,	143		1,039		360	325	1,867

NOTE.—Time is classified in the first two columns so as to show the number of storms for every difference of thirty minutes. In the third column there is given the approximate time as reported by observer.

Table No. 8.

DIRECTION OF PROGRESSIVE MOVEMENT OF TORNADO-CLOUD.

Direction.	No. of Cases.	Direction.	No. of Cases.	Direction.	No. of Cases.	Direction.	No. of Cases.	No. of Cases. direction not recorded.	Total No. of Tornadoes observed.
N	9	Little S of E	1	N 40° E	2	S 85° E	2		
N N E	43	Easterly.	38	N 50° B	7	S 84° E	1		
N E	935	E of N	1	N 55° E	2	S 80° E	10		
E N E	54	S E and then E	1	N 56° E	1	S 70° E	12		
E	123	N 2° E	1	N 60° E	10	S 65° E	2		
E by S	1	N 10° E	1	N 65° E	30	S 60° E	4		
E S E	32	N 12° E	1	N 70° E	26	S 50° E	2		
S E	122	N 15° E	1	N 72° E	2	S 40° E	1		
S S E	6	N 18° E	1	N 75° E	4	S 20° E	1		
S	6	N 20° E	2	N 78° E	1	N 20° W	1		
S S W	1	N 23° E	1	N 80° E	24	N 10° W	1		
S W	3	N 25° E	1	N 84° E	1				
N W	4	N 30° E	2	N 85° E	2				
		N 33° E	1						
Totals,	1,339		53		112		37	326	1,867

Table No. 9.

FORM OF TORNADO-CLOUD.

Formation.	No. of Cases.	Formation.	No. of Cases.	Formation.	No. of Cases.	Formation.	No. of Cases.	No. of Cases form not recorded.	Total No. of Tornadoes observed.
"Funnel."	981	"Inverted cone."	24	"Balloon."	20	"Whirlwind."	14		
"Hour-glass,"	11	"Cone."	10	"Waterspout."	6	"Inverted funnel."	5		
"Basket."	4	"Serpent."	4	"Cylindrical."	3	"Elephant's trunk."	2		
"Acorn."	1	"Turnip."	1	"Pear."	1	"Ball."	1		
"Column."	1	"Hogshead."	1	"Twister."	1	"Whirl."	1		
"Dark mass."	1	"Heavy rolling."	1	"Huge Serpent."	1	"Local Whirlwind."	1		
"Rolling cloud."	1	"Dense rolling	1	"Dense rolling mass"	1	"A grayish, fluffy mass."	1		
"Black circular cloud."	1	"Streams, 20 in number."	1	"Dense cloud of scowling blackness."	1	"Immense dark whirling mass."	1		
"Clouds rolled like a barrel."	1	"Large masses, as if white spray fell to the earth."	1	"Two funnels small ends together."	1	"Large revolving cloud sent funnel roots to the ground."	1		
"A long streak like a spout reaching from bottom of cloud to earth."	1								
Totals.	1,003		44		35		27	758	1,867

Table No. 10. TEMPERATURE BEFORE THE TORNADO.

Condition	No. of Cases.	Condition.	No. of Cases.	Condition. (Thermometrically.)	No. of Cases.	Condition.] (Thermometrically.)	No. of Cases.	No. of Cases Temperat'e not recorded	Total No. of Tornadoes observed.
"Hot."	12	"Alternate suction of cold and hot air (before)."	1			80° (Aug.)	2		
"Very hot."	24			47° 5 (May7th—a.m.)	1	80° (May.)	1		
"Hot and sultry."	12			50° (April.)	1	80° (June.)	1		
"Very hot and sultry."	2			54° (Nov.)	1	81° (Sept.)	1		
"Intensely hot."	1			60° (Feb.)	1	82° (Aug.)	1		
"Unusually hot."	1			60° (March.)	1	82° (July.)	1		
"Sultry."	86			62° (March.)	1	82° (June.)	2		
"Very sultry."	29			65° (May.)	1	82° (May.)	1		
"Warm."	311			65° (July.)	1	83° (June.)	1		
"Very warm."	105			68° (Sept.)	1	83° (April.)	1		
"Moderately warm."	5			68° (May.)	1	84° (July.)	1		
"Warm and sultry."	25			68° (June.)	1	84° (June.)	2		
"Close and sultry."	1			70° (April.)	2	85° (May.)	1		
"Very warm and sultry."	1			70° (Nov.)	1	85° (April.)	2		
"Not unusually warm."	4			70° (Oct.)	1	85° (Aug.)	1		
"Unusually warm."	18			70° (Aug.)	1	86° (June.)	1		
"Hot and oppressive."	1			70° (Feb.)	1	87° (May.)	1		
"Hot and stifling."	1			70° (March.)	1	89° (July.)	1		
"Oppressive."	14			60° to 80° (March.)	1	90° (July.)	2		
"Unusually warm and oppressive."	1			70° (May.)	1	90° (June.)	7		
"Not very warm."	1			72° (Sept.)	1	90° (May.)	1		
"Warm and oppressive."	1			72° (Aug.)	1	90° (Aug.)	1		
"High."	1			72° (July.)	1	92° (April.)	3		
"Very close."	1			74° (Nov.)	1	92° (May.)	1		
"Rather cool."	1			74° (May.)	1	92° (June.)	2		
"Cool."	3			75° (Oct.)	1	95° (July.(	1		
"Oppressive, damp, and heavy."	1			70° to 80° (April.)	1	95° (June.)	1		
"Dry and pleasant."	1			75° (April.)	2	95° (Aug.)	1		
"Rather cool (before), had been hot for several days preceding day of storm."	1			75° (May.)	1	96° (June.)	5		
				76° (April.)	2	97° (June.)	1		
				78° (April.)	2	98° (Aug.)	1		
				78° (May.)	1	99° (Aug.)	1		
				80° (April.)	1	105° (Aug.)	1		
				80° (Feb.)	1	110° (Aug.)	1		
Totals,	665		1		37		52	1,112	1,867

Table No. 11.

TEMPERATURE AFTER THE TORNADO.

CONDITION.	No. of Cases.	CONDITION. (Thermometrically.)	No. of Cases.	CONDITION. (Thermometrically.)	No. of Cases.	No. of Cases Temperat'e not recorded	Total No. of Tornadoes observed.
"Cooler and chilly."	1						
"Cooler (next day)."	1						
"Chilly."	45	8° (Nov., next morn)	1	66° (April.)	1		
"Cool."	188			68° (June.)	1		
"Cooler."	49	45° (May.)	1	68° (May.)	1		
"Slightly cooler."	5						
"Much cooler."	1	50° (June.)	1	69° (May.)	1		
"Probably cooler."	1						
"Cold."	123	54° (April.)	1	70° (July.)	1		
"Very cold."	8						
"Suddenly very cold."	1	56° (April.)	2	72° (June.)	1		
"Colder."	8						
"Much colder."	1	56° (June.)	2	73° (Aug.)	1		
"Gradually cooler."	28						
"Gradually cold."	6	58° (May.)	1	75° (July.)	1		
"Gradually cool."	2						
"Gradually colder."	16	60° (June.)	2	75° (June.)	1		
"Suddenly cooler."	11						
"Suddenly cool."	3	60° (April.)	2	80° (Oct.)	1		
"Suddenly cold."	34						
"Suddenly cold (snow after, next day)."	1	60° (Aug.)	2	81° (June.)	1		
"Suddenly colder."	8	62° (May.)	1				
"No change."	6						
"No decided change."	3	64° (May.)	1				
"No great change."	3						
"Not much change."	1	65° (June.)	1				
"No sudden change."	1						
"Warm."	8	65° (Sept.)	1				
"Intensely hot."	1						
"Suddenly cool, temperature falling several degrees in a few minutes."	1	66° (Sept.)	1				
		66° (July.)	1				
Totals,	565		21		11	1,270	1,867

Table No. 12.

Reported Valuation of Property Destroyed by Tornadoes. The values here given are in the main largely underestimated, owing to imperfection of reports, and in many cases failure to give any mention of the loss. It is estimated that these values give, on the average, about 10 per cent of the actual loss sustained.

STATES.	Length of Tornado record in years.	Valuation of property destroyed.	STATES.	Length of Tornado record in years.	Valuation of property destroyed.
Alabama,	63	$142,000	Minnesota,	32	$5,575,000
Arkansas,	46	535,000	Mississippi	64	1,751,500
Connecticut,	205	272,000	Missouri,	46	2,785,000
Dakota,	12	540,000	Nebraska,	16	54,000
Florida,	12	2,500	N. Hampshire,	70	4,000
Georgia,	92	600,000	New Jersey,	65	625,000
Illinois,	52	675,000	New York,	99	200,000
Indiana,	68	787,000	North Carolina,	61	225,000
Iowa,	44	1,553,000	Ohio,	83	7,883,000
Kansas,	28	520,000	Pennsylvania,	76	875,000
Kentucky,	77	25,000	South Carolina,	125	625,000
Louisiana,	18	120,000	Tennessee,	79	140,000
Maine	27	2,000	Texas,	34	251,000
Maryland,	54	20,000	Vermont,	58	20,000
Massachusetts,	78	50,000	Virginia,	71	15,000
Michigan,	64	226,400	Wisconsin,	43	1,105,000

Table No. 13.

A table showing the period of observation and record of the occurrence of Tornadoes for each State from which they have been reported. States arranged alphabetically.

STATE.	PERIOD.	No. of Years.	STATE.	PERIOD.	No. of Years.
Alabama,	1823 to 1886	63	Minnesota,	1855 to 1886	32
Arkansas,	1840 " 1886	46	Mississippi,	1823 " 1886	64
Colorado,	1877 " 1886	10	Missouri,	1814 " 1886	46
Connecticut,	1682 " 1886	205	Nebraska,	1871 " 1886	16
Dakota,	1875 " 1886	12	N. Hampshire,	1807 " 1886	70
Florida,	1875 " 1886	12	New Jersey,	1822 " 1886	65
Georgia,	1795 " 1886	92	New York,	1787 " 1886	99
Illinois,	1835 " 1886	52	North Carolina,	1826 " 1886	61
Indiana,	1818 " 1886	68	Ohio,	1804 " 1886	83
Iowa,	1843 " 1886	44	Pennsylvania,	1811 " 1886	76
Kansas,	1859 " 1886	28	South Carolina,	1761 " 1886	125
Kentucky,	1810 " 1886	77	Tennessee,	1808 " 1886	79
Louisiana,	1869 " 1886	18	Texas,	1853 " 1886	34
Maine,	1860 " 1886	27	Vermont,	1829 " 1886	58
Maryland,	1833 " 1886	54	Virginia,	1816 " 1886	71
Massachusetts,	1809 " 1886	78	West Virginia,	1880 " 1886	7
Michigan,	1823 " 1886	64	Wisconsin,	1844 " 1886	43

Table No 14.

RELATIVE FREQUENCY OF TORNADOES, BY MONTHS.

MONTHS.	No. of Storms	MONTHS.	No. of Storms	No. Storms, month not recorded.	Total No. of Tornadoes observed.
JANUARY,	22	JULY,	232		
FEBRUARY,	89	AUGUST,	147		
MARCH,	152	SEPTEMBER,	114		
APRIL,	313	OCTOBER,	41		
MAY,	339	NOVEMBER,	55		
JUNE,	285	DECEMBER,	27	51	1,867

Table No. 15.

A table showing the relative frequency of Tornadoes by States according to the area of each in square miles, and to the length of record of observations during a period, in the total, of 205 years, from 1682 to 1886, inclusive.

Relative frequency in this table is expressed decimally in terms of the unit of value for each State, which is taken, for convenience of comparison, at 10,000 square miles.

STATES.	Area in units of 10,000 square miles.	Length of Tornado record in years.	Average number per year for each State.	Average number per year for 10,000 sq. miles.	STATES.	Area in units of 10,000 square miles.	Length of Tornado record in years.	Average number per year. for each State.	Average number per year for 10,000 sq. miles.
Alabama,	5.1	63	1.62	0.32	Minnesota,	8.4	32	2.44	0.29
Arkansas,	5.3	46	0.74	0.14	Mississippi,	4.7	64	0.76	0.16
Colorado,	10.3	10	0.40	0.04	Missouri,	6.5	46	3.39	0.52
Connecticut,	0.5	205	0.06	0.12	Nebraska,	7.6	16	3.25	0.43
Dakota,	14.7	12	3.83	0.26	N. Hampshire	7.9	70	0.11	0.01
Florida,	5.4	12	0.83	0.15	New Jersey,	0.8	65	0.18	0.22
Georgia,	5.8	92	1.39	0.24	New York,	4.7	99	0.68	0.14
Illinois,	5.5	52	2.44	0.44	N. Carolina,	5.1	61	0.97	0.19
Indiana,	3.4	68	1.23	0.36	Ohio,	4.0	83	1.10	0.27
Iowa,	5.5	44	2 67	0.49	Pennsylvania	4.6	76	0.80	0.17
Kansas,	8.1	28	5.46	0.67	S. Carolina,	3.4	125	0.46	0.13
Kentucky,	4.0	77	0.34	0.08	Tennessee,	4.6	79	0.39	0.08
Louisiana,	4.1	18	1.05	0.26	Texas,	26.2	34	2.14	0.08
Maine,	2.9	27	0.26	0.09	Vermont,	0.9	58	0.06	0.07
Maryland,	1.1	54	0.30	0.27	Virginia,	4.0	71	0.25	0.06
Massachus'tts	0.8	78	0.28	0.35	W. Virginia,	2.4	7	0.28	0.12
Michigan,	5.6	64	1.10	0.20	Wisconsin,	5.4	43	1.37	0.25

Table No. 16.

STATE.	MONTHLY TORNADO FREQUENCY. TOTAL NUMBER OF TORNADOES FOR EACH MONTH, BY STATES.												Cases, months not reported.	Total No. of Tornadoes per State.
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.		
Alabama,	9	13	27	21	9	..	..	..	..	..	9	5	9	102
Arkansas,	..	..	2	12	9	2	3	..	..	1	4	..	1	34
Colorado,	..	..	..	..	2	2	..	..	..	..	..	..	..	4
Connecticut,	..	..	..	..	1	2	3	3	2	1	..	..	1	13
Dakota Ty.,	..	..	2	5	2	8	14	11	4	..	..	..	..	46
Delaware,	..	..	..	..	..	..	..	1	..	..	..	..	..	1
Dist. of Columbia,	..	..	..	..	..	..	..	1	..	..	..	..	..	1
Florida,	..	..	..	1	1	..	2	..	3	2	1	..	..	10
Georgia,	4	27	30	30	8	4	7	..	3	2	2	5	6	128
Illinois,	1	1	6	15	50	19	4	5	15	1	6	1	3	127
Indiana,	..	2	7	6	25	13	9	7	6	3	4	1	1	84
Indian Ty.,	..	..	..	2	3	..	..	1	..	..	..	..	..	6
Iowa,	..	2	1	31	18	37	15	3	3	6	2	..	..	118
Kansas,	..	..	4	30	45	40	18	8	7	..	1	..	..	153
Kentucky,	..	3	6	..	3	2	3	2	..	..	2	2	3	26
Louisiana,	..	2	1	7	1	..	1	..	..	2	5	..	..	19
Maine,	..	..	..	..	1	..	4	1	..	1	..	..	..	7
Maryland,	1	1	..	..	1	1	4	6	1	1	..	..	..	16
Massachusetts,	..	..	..	..	..	3	9	5	2	..	..	..	3	22
Michigan,	..	1	..	11	14	8	7	5	15	4	2	..	4	71
Minnesota,	..	..	..	16	4	15	20	17	3	1	1	..	1	78
Mississippi,	1	2	15	19	8	1	..	1	..	..	1	..	1	49
Missouri.	..	4	5	32	42	29	13	5	8	2	6	6	4	156
Nebraska,	..	..	..	8	11	18	6	2	6	1	..	..	..	52
New Hampshire,	..	..	..	..	1	..	4	1	1	1	..	..	..	8
New Jersey,	..	..	..	1	..	1	2	3	2	2	1	..	..	12
New York,	..	1	2	..	5	8	28	9	7	1	1	..	5	67
North Carolina,	..	8	14	11	3	3	3	4	4	4	1	3	1	59
Ohio,	2	6	6	6	32	15	9	6	4	2	1	1	2	92
Pennsylvania,	1	..	3	2	13	12	9	13	4	1	..	1	2	61
Rhode Island,	..	..	..	..	..	..	..	1	..	..	..	..	..	1
South Carolina,	..	13	11	12	6	1	4	2	4	..	1	1	2	57
Tennessee,	1	3	3	10	4	3	1	3	..	..	1	1	1	31
Texas,	2	..	4	22	8	26	4	5	..	..	2	..	..	73
Vermont,	..	..	..	..	1	..	2	1	..	..	..	..	..	4
Virginia,	..	..	2	..	1	3	5	2	5	..	..	..	..	18
West Virginia,	..	..	..	1	..	1	..	..	..	..	..	..	..	2
Wisconsin,	..	..	1	2	7	8	19	13	5	2	1	..	1	59
TOTALS,	22	89	152	313	339	285	232	147	114	41	55	27	51	1,867

Table No. 17.

STATE.	MONTHLY FREQUENCY EXPRESSED IN PERCENTAGE OF TOTAL NUMBER OF TORNADOES IN EACH STATE.												Month of greatest frequency, per cent.
	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
Alabama,	10	14	29	23	10	..	..	..	..	..	10	5	March.
Arkansas,	..	..	6	36	27	6	9	..	..	3	12	..	April.
Colorado,	..	..	..	..	50	50	..	..	..	..	..	..	May, Jun.
Connecticut,	..	..	..	..	8	17	25	25	17	8	..	..	July.
Dakota Ter.,	..	..	4	11	4	18	30	24	9	..	..	..	July.
Delaware,	..	..	..	..	..	..	..	100	..	..	..	..	August.
Dist. of Columbia,	..	..	..	..	..	..	..	100	..	..	..	..	August.
Florida,	..	..	..	10	10	..	20	..	30	20	10	..	Sept.
Georgia,	3	22	25	25	7	3	6	..	2	2	2	4	Mch, Apr.
Illinois,	1	1	5	12	40	15	3	4	12	1	5	1	May.
Indiana,	..	2	8	7	30	16	11	8	7	4	5	1	May.
Indian Ter.,	..	..	..	33	50	..	..	17	..	..	..	..	May.
Iowa,	..	2	1	26	15	31	13	3	3	5	2	..	June.
Kansas,	..	..	3	20	29	26	12	5	5	..	1	..	May.
Kentucky,	..	13	26	13	..	9	13	9	..	..	9	9	March.
Louisiana,	..	11	5	37	5	..	5	..	..	11	26	..	April.
Maine,	..	..	..	..	14	..	57	14	..	14	..	..	July.
Maryland,	..	7	..	..	7	7	27	40	7	7	..	..	August.
Massachusetts,	..	16	..	..	..	..	47	26	11	..	..	..	July.
Michigan,	..	2	..	16	21	12	10	8	22	6	3	..	May.
Minnesota,	..	..	..	21	5	20	26	22	4	1	1	..	July.
Mississippi,	2	4	31	38	17	2	2	2	..	..	..	..	April.
Missouri,	..	3	3	21	28	19	9	3	5	1	4	4	May.
Nebraska,	..	..	..	15	21	35	12	4	12	2	..	..	June.
New Hampshire,	..	..	..	..	12	..	50	12	12	12	..	..	July.
New Jersey,	..	..	..	8	..	8	17	25	17	17	8	..	August.
New York,	..	2	3	..	8	13	45	14	11	2	2	..	July.
North Carolina,	..	14	24	19	5	5	5	7	7	7	2	5	March.
Ohio,	2	7	7	7	36	17	10	7	4	2	1	1	May.
Pennsylvania,	2	..	5	3	22	20	15	22	7	2	..	2	May, Aug.
Rhode Island,	..	..	..	..	..	..	..	100	..	..	..	..	August.
South Carolina,	..	24	20	22	11	2	7	4	7	..	2	2	February
Tennessee,	3	10	10	33	13	10	3	10	..	..	3	3	April.
Texas,	3	..	6	30	11	36	6	7	..	..	3	..	June.
Vermont,	..	..	..	..	25	..	50	25	..	..	..	..	July.
Virginia,	..	..	11	..	6	17	28	11	28	..	..	..	July, Sep.
West Virginia,	..	..	..	50	..	50	..	..	..	..	..	..	Apl, June.
Wisconsin,	..	..	2	3	12	14	33	22	9	3	2	..	July.

Table No. 18.

RELATIVE FREQUENCY OF TORNADOES.

MONTHS—DAYS.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1st.	1	..	1	15	10	5	9	6	2	2	..	..
2d.	..	..	1	6	2	7	10	2	..	..	..	..
3d.	..	1	..	5	1	7	11	17	3	1	..	..
4th.	..	2	5	4	2	3	14	..	2	1	..	5
5th.	..	..	1	6	6	10	10	7	..	1	5	..
6th.	..	..	1	11	16	9	2	3	..	1	14	1
7th.	..	..	1	6	3	7	6	1	..	1	1	..
8th.	..	2	2	3	11	7	10	3	6	6	5	1
9th.	2	4	..	1	13	8	7	5	9	2	1	1
10th.	..	1	7	2	18	11	9	4	3	1	1	2
11th.	8	2	14	2	6	21	10	3	4	4	2	..
12th.	1	4	3	7	37	28	5	2	11	1	1	2
13th.	..	2	..	4	18	7	17	5	1	..	..	..
14th.	..	2	..	62	32	17	3	6	1	2	6	..
15th.	..	1	3	6	5	4	8	15	1	4	..	..
16th.	1	..	3	8	6	10	15	4	21	..	1	1
17th.	..	..	1	2	6	9	1	2	2	1	..	..
18th.	..	2	4	38	31	9	5	3	3	2	..	..
19th.	..	51	1	6	3	20	4	2	2	..	..	..
20th.	2	..	25	6	9	9	5	4	3	2	..	1
21st.	..	1	1	9	2	13	8	11	1	..	1	..
22d.	..	..	5	22	7	5	3	11	2	..	2	4
23d.	..	2	2	12	8	3	7	2	1	..	1	..
24th.	1	1	8	9	2	7	2	3	6	..	..	3
25th.	..	..	27	13	7	7	6	6	1	1	4	2
26th.	..	1	3	7	5	3	9	2	4	..	..	2
27th.	..	6	12	8	12	3	3	4	1	..	1	..
28th.	..	1	5	7	6	4	7	3	3	1	2	..
29th.	1	..	7	9	7	6	4	4	16	2	..	1
30th.	..	..	1	5	26	8	10	2	2	2	1	..
31st.	..	..	2	..	9	..	4	2	..	..	..	..
No. of Days.	8	18	27	30	31	30	31	30	26	20	17	13
No. of cases, days not recorded.	4	3	6	12	13	18	8	3	3	3	6	1
No. of Tornadoes per month.	22	89	152	313	339	285	232	147	114	41	55	27

Number of cases month not recorded, 51.

Total Number of Tornadoes observed, 1,867.

TABLE No. 19.

CONSIDERATION OF STATES BY QUARTERS.

STATE.	Number of Years of Tornado Record.	Total Number of Tornadoes.	N.E. Quarter		S. E. Quarter		S.W. Quarter		N.W. Quart'r	
			Total Number of Tornadoes.	Month of greatest frequency.	Total Number of Tornadoes.	Month of greatest frequency.	Total Number of Tornadoes.	Month of greatest frequency.	Total Number of Tornadoes.	Month of greatest frequency.
Alabama.	63	102	57	April.	8	March.	8	Mh.Nov.	29	March.
Arkansas.	46	34	9	May.	4	March.	5	April.	15	April.
Colorado.	10	4	1	May.	3	June.				
Conn.	205	13	2	Jul., Sep.			6	Jun., Ag.	5	May,Jul. Ag., Sep.
Dakota.	12	46	12	August.	27	July.	3	June.	2	March.
Delaware.	1	1							1	Aug.
D.Columbia.	72	1								
Florida.	12	10	5	Sept.	1	July.			4	Ap.,May Jul.,Sep.
Georgia.	92	128	33	Feb.	10	March.	19	April.	65	April.
Illinois.	52	127	30	May	13	Sept.	55	May.	29	May.
Indiana.	68	84	23	May.	28	May.	22	Aug.	11	May.
Indian Ty.	12	6	1	May.	3	May.			2	April.
Iowa.	44	118	20	May.	34	June.	34	April.	30	June.
Kansas.	28	153	87	May.	39	June.	12	April.	15	May.
Kentucky.	77	26	8	Mh., Jul.	7	March.	7	Dec.	4	Fb., May. Ag. Nov.
Louisiana.	18	19	2	Oc.,Nov.	8	April.	1	Oct.	8	Ap., Nov
Maine.	27	7			2	May,Jul.	5	July.		
Maryland.	54	16	5	August.	1	Aug.	3	Fb., Ag., Sept.	7	July.
Mass.	78	22	7	August.	2	Jul., Ag.	9	July.	4	July.
Michigan.	64	71	5	Ap., Jun, Sept.	34	April.	29	May.	4	Sep.,Oct.
Minnesota.	32	78	2	Ap.,May	45	Jun., Ag.	22	July.	9	Aug.
Mississippi.	64	49	20	March.	8	April.	17	April.	6	April.
Missouri.	63	156	36	May.	21	April.	31	April.	72	My., Jun
Nebraska.	16	52	11	Sept.	39	June.	2	My.,Jun.		
N. Hamp.	70	8			1	Oct.	7	July.		
New Jersey.	65	12	6	Oct.	1	Aug.	4	Jul., Ag., Sep.,Nov	1	April.
New York.	99	67	7	August.	19	July.	32	July.	9	July.
N. Carolina.	61	59	10	August.	14	Feb.,Mh.	22	March.	10	April.
Ohio.	83	92	21	June.	11	May.	29	May.	31	May.
Penn.	76	61	6	Oct.	22	Aug.	24	May.	9	Jun.,Jul.
Rhode Is.	48	1	1	Aug.						
S. Carolina.	125	57	8	March.	8	April.	15	Fb., Apr.	25	March.
Tennessee.	79	31	6	Ap., Jun.	3	Fb., Ap., Nov.	11	April.	13	April.
Texas.	34	73	51	June.	14	June.	4	April.	3	April.
Vermont.	58	4	3	Ma.,Jul., Aug.	1	July.				
Virginia.	71	18	5	Sept.	9	July.	3	June.	1	June.
W. Virginia.	7	2					1	June.	1	April.
Wisconsin.	43	59	4	July.	30	July.	21	Aug.	5	July.
Totals	2,129	1,867	504		470		463		430	

NOTE.—In preparing table 19 (see opposite page), the data for each State was carefully charted on a large county map. The State was then divided into four approximately equal portions, making four quarters denominated N. E., S. E., S. W., and N. W. quarters. The data for each was considered by itself in determining the peculiar value of that section, and afterwards the four sections of each State were tabulated and brought together in convenient form for comparative study, as indicated on page 122.

Table No. 20.

Month.	Total No. of Years.	Total No. of Tornadoes.	Average yearly No. of Tornadoes.	Total number of Tornadoes per State.		Average yearly No. of Tornadoes per State.	Year of Maximum Frequency.	Year of Minimum Frequency.	Region of Maximum Frequency.
JANUARY	8	22	2.75	Alabama	9	1.12	1885	1866, 1869, 1870, 1883	Alabama.
				Georgia	4	.50			
				Illinois	1	.12			
				Mississippi	1	.12			
				Ohio	2	.25			
				Pennsylvania	1	.12			
				Tennessee	1	.12			
				Texas	2	.25			
FEBRUARY	17	89	5.23	Alabama	13	.76	1884	1805, 1820, 1854, 1867, 1868, 1871, 1882, 1883	Georgia.
				Georgia	27	1.59			
				Illinois	1	.06			
				Indiana	2	.12			
				Iowa	2	.12			
				Kentucky	3	.18			
				Louisiana	2	.12			
				Maryland	11	.06			
				Michigan	1	.06			
				Mississippi	2	.12			
				Missouri	4	.24			
				New York	1	.06			
				No. Carolina	8	.47			
				Ohio	6	.35			
				So. Carolina	13	.76			
				Tennessee	3	.18			
MARCH	25	152	6.04	Alabama	27	1.08	1884	1849, 1854, 1855, 1856, 1857, 1861, 1863, 1865, 1871, 1872, 1874	Georgia.
				Arkansas	2	.08			
				Dakota	2	.08			
				Georgia	30	1.20			
				Illinois	6	.24			
				Indiana	7	.28			
				Iowa	1	.04			
				Kansas	4	.16			
				Kentucky	6	.24			
				Louisiana	1	.04			
				Mississippi	15	.60			
				Missouri	5	.20			
				New York	2	.08			
				No. Carolina	14	.56			
				Ohio	6	.24			
				Pennsylvania	3	.12			
				So. Carolina	11	.44			
				Tennessee	3	.12			
				Texas	4	.16			
				Virginia	2	.08			
				Wisconsin	1	.04			

Table No. 20—Continued.

Month.	Total No. of Years.	Total No. of Tornadoes.	Average yearly No. of Tornadoes.	Total number of Tornadoes per State.		Average Yearly No. of Tornadoes per State.	Year of Maximum Frequency.	Year of Minimum Frequency.	Region of Maximum Frequency.
				Alabama	21	.62			
				Arkansas	12	.35			
				Dakota	5	.15			
				Florida	1	.03			
				Georgia	30	.88		1804	
				Illinois	15	.44		1819	
				Indiana	6	.18		1823	
				Indian Ter.	2	.06		1827	
				Iowa	31	.91		1829	
				Kansas	30	.88		1830	
				Louisiana	7	.21		1832	
				Michigan	11	.32		1833	
APRIL	34	313	9.21	Minnesota	16	.47	1886	1834	Iowa and Missouri.
				Mississippi	19	.56		1837	
				Missouri	32	.94		1843	
				Nebraska	8	.24		1852	
				New Jersey	1	.03		1860	
				No. Carolina	11	.32		1865	
				Ohio	6	.18		1866	
				Pennsylvania	2	.06		1873	
				So. Carolina	12	.35		1874	
				Tennessee	10	.29			
				Texas	22	.65			
				West Virginia	1	.03			
				Wisconsin	2	.06			
				Alabama	9	.26			
				Arkansas	9	.26			
				Colorado	2	.06			
				Connecticut	1	.03			
				Dakota	2	.06			
				Florida	1	.03			
				Georgia	8	.23			
				Indian Ter.	1	.03			
				Illinois	50	1.43		1761	
				Indiana	25	.71		1808	
				Indian Ter.	3	.11		1809	
				Iowa	18	.51		1823	
				Kansas	45	1.29		1831	
				Kentucky	3	.09		1832	
				Louisiana	1	.03		1834	
				Maine	1	.03		1835	
MAY	35	339	9.40	Maryland	1	.03	1886	1837	Illinois.
				Michigan	14	.40		1838	
				Minnesota	4	.11		1839	
				Mississippi	8	.23		1840	
				Missouri	42	1.20		1854	
				Nebraska	11	.31		1855	
				New Hamp.	1	.03		1860	
				New York	5	.14		1867	
				No. Carolina	3	.09		1870	
				Ohio	32	.91			
				Penn.	13	.37			
				So. Carolina	6	.17			
				Tennessee	4	.11			
				Texas	8	.23			
				Vermont	1	.03			
				Virginia	1	.03			
				Wisconsin	7	.20			

Table No. 20.—Continued.

Month.	Total No. of Years.	Total No. of Tornadoes.	Average yearly No. of Tornadoes.	Total number of Tornadoes per State.		Average yearly No. of Tornadoes per State.	Year of Maximum Frequency.	Year of Minimum Frequency.	Region of Maximum Frequency.
				Arkansas	2	.06			
				Colorado	2	.06			
				Connecticut	2	.06			
				Dakota	8	.22			
				Georgia	4	.11			
				Illinois	19	.72			
				Indiana	13	.36		1682	
				Iowa	37	1.03		1794	
				Kansas	40	1.11		1829	
				Kentucky	2	.06		1840	
				Maryland	1	.03		1841	
				Mass.	3	.08		1843	
				Michigan	8	.22		1845	
JUNE........	36	285	7.91	Minnesota	15	.42	1886	1854	Kansas.
				Mississippi	1	.03		1855	
				Missouri	29	.81		1864	
				Nebraska	18	.50		1865	
				New Jersey	1	.03		1867	
				New York	8	.22		1869	
				No. Carolina	3	.08		1870	
				Ohio	15	.42		1872	
				Penn.	12	.33		1873	
				So. Carolina	1	.03			
				Tennessee	3	.08			
				Texas	26	.72			
				Virginia	3	.08			
				W. Virginia	1	.03			
				Wisconsin	8	.22			
				Arkansas	3	.09			
				Connecticut	3	.09			
				Dakota	14	.44			
				Florida	2	.06			
				Georgia	7	.22			
				Illinois	4	.12			
				Indiana	9	.28			
				Iowa	15	.47			
				Kansas	18	.56			
				Kentucky	3	.12			
				Louisiana	1	.03		1814	
				Maine	4	.12		1816	
				Maryland	4	12		1831	
				Mass.	9	.28		1834	
				Michigan	7	.22		1845	
JULY........	32	232	7.24	Minnesota	20	.62	1884	1850	New York.
				Missouri	13	.41		1854	
				Nebraska	6	.19		1861	
				New Hamp.	4	.12		1867	
				New Jersey	2	.06		1870	
				New York	28	.88			
				No. Carolina	3	.09			
				Ohio	9	.28			
				Penn.	9	.28			
				So. Carolina	4	.12			
				Tennessee	1	.03			
				Texas	4	.12			
				Vermont	2	.06			
				Virginia	5	.16			
				Wisconsin	19	.59			

Table No. 20.—Continued.

Month.	Total No. of Years.	Total No. of Tornadoes.	Average yearly No. of Tornadoes.	Total number of Tornadoes per State.		Average yearly No. of Tornadoes per State.	Year of Maximum Frequency.	Year of Minimum Frequency.	Region of Maximum Frequency.
AUGUST.....	35	147	4.19	Connecticut	3	.09	1886	1787 1818 1822 1823 1827 1834 1838 1843 1844 1852 1858 1859 1860 1862 1870 1879	Minnesota
				Dakota	11	.31			
				Delaware	1	.03			
				Dist. Col.	1	.03			
				Illinois	5	.14			
				Indiana	7	.20			
				Indian Ter.	1	.03			
				Iowa	3	.09			
				Kansas	8	.23			
				Kentucky	2	.06			
				Maine	1	.03			
				Maryland	6	.17			
				Mass.	5	.14			
				Michigan	5	.14			
				Minnesota	17	.49			
				Mississippi	1	.03			
				Missouri	5	.14			
				Nebraska	2	.06			
				New Hamp.	1	.03			
				New Jersey	3	.09			
				New York	9	.26			
				No. Carolina	4	.11			
				Ohio	6	.17			
				Penn.	13	.37			
				Rhode Island	1	.03			
				So. Carolina	2	.06			
				Tennessee	3	.09			
				Texas	5	.14			
				Vermont	1	.03			
				Virginia	2	.06			
				Wisconsin	13	.37			
SEPTEMBER.	20	114	5.71	Connecticut	2	.10	1886	1811 1822 1845 1848 1857 1867 1872 1873 1876	Illinois and Michigan.
				Dakota	4	.20			
				Florida	3	.15			
				Georgia	3	.15			
				Illinois	15	.75			
				Indiana	6	.30			
				Iowa	3	.15			
				Kansas	7	.35			
				Maryland	1	.05			
				Mass.	2	.10			
				Michigan	15	.75			
				Minnesota	3	.15			
				Missouri	8	.40			
				Nebraska	6	.30			
				New Hamp.	1	.05			
				New Jersey	2	.10			
				New York	7	.35			
				No. Carolina	4	.20			
				Ohio	4	.20			
				Penn.	4	.20			
				So. Carolina	4	.20			
				Virginia	5	.25			
				Wisconsin	5	.25			

Table No. 20.—Continued.

Month.	Total No. of Years.	Total No. of Tornadoes.	Average yearly No. of Tornadoes.	Total number of Tornadoes per State.		Average yearly No. of Tornadoes per State.	Year of Maximum Frequency.	Year of Minimum Frequency.	Region of Maximum Frequency.
OCTOBER....	20	41	2.05	Arkansas	1	.05	1883	1797 1824 1826 1833 1834 1835 1837 1844 1847 1854 1872 1880	Iowa.
				Connecticut	1	.05			
				Florida	2	.10			
				Georgia	2	.10			
				Illinois	1	.05			
				Indiana	3	.15			
				Iowa	6	.30			
				Louisiana	2	.10			
				Maine	1	.05			
				Maryland	1	.05			
				Michigan	4	.20			
				Minnesota	1	.05			
				Missouri	2	.10			
				Nebraska	1	.05			
				New Hamp.	1	.05			
				New Jersey	2	.10			
				New York	1	.05			
				No. Carolina	4	.20			
				Ohio	2	.10			
				Pennsylvania	1	.05			
				Wisconsin	2	.10			
NOVEMBER.	14	55	3.96	Alabama	9	.64	1885	18[illegible]1 1870 1870 1875 1876 1882 1884	Alabama.
				Arkansas	4	.29			
				Florida	1	.07			
				Georgia	2	.14			
				Illinois	6	.43			
				Indiana	4	.29			
				Iowa	2	.14			
				Kansas	1	.07			
				Kentucky	2	.14			
				Louisiana	5	.36			
				Michigan	2	.14			
				Minnesota	1	.07			
				Mississippi	1	.07			
				Missouri	6	.43			
				New Jersey	1	.07			
				New York	1	.07			
				No. Carolina	1	.07			
				Ohio	1	.07			
				So. Carolina	1	.07			
				Tennessee	1	.07			
				Texas	2	.14			
				Wisconsin	1	.07			
DECEMBER..	10	27	2.70	Alabama	5	.50	1884	1864 1870 1878 1883	Missouri.
				Georgia	5	.50			
				Illinois	1	.10			
				Indiana	1	.10			
				Kentucky	1	.10			
				Missouri	6	.60			
				Nevada	1	.10			
				No. Carolina	3	.30			
				Ohio	1	.10			
				Pennsylvania	1	.10			
				So. Carolina	1	.10			
				Tennessee	1	.10			

Table No. 21

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months.											
				Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
ALABAMA,	102	March.	6 to 7 p. m. 7 to 8 p. m. 11 p. m. to midnight.	11, 16, 29.	12, 13, 15, 18, 19, 24, 26, 28.	4, 6, 7, 10, 11, 12, 15, 16, 18, 20, 22, 23, 24, 25, 27, 28.	1, 2, 6, 12, 16, 22, 23, 25, 29.	1, 4, 6, 8, 24, 26.						6, 16, 22, 27, 30.	12, 24, 25.
ARIZONA,	3		3 to 4 p.m.		19.					31.				21.	
ARKANSAS	34	April.	1 to 2 p.m. 5 to 6 p.m. 6 to 7 p.m. 7 to 8 p.m.			29.	5, 12, 13, 14, 18, 25, 28.	5, 6, 8, 18.	6, 27.	3, 15, 27.				5, 8, 21, 25.	
COLORADO,	4	May, June.	2 to 3 p.m.					16, 18.	6, 24.						
CONNECTICUT,	13	July, August.	6 to 7 p.m.					29.	10, 19.	9, 30, 31.	9, 13, 20.	12, 14.	7.		

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months.											
				Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
DAKOTA,	46	July.	6 to 7 p.m.			15, 24.	14, 16, 27.	20, 25.	6, 11, 12.	2, 5, 11, 13, 14, 15, 18, 19, 21, 23, 28.	10, 15, 18, 26, 28.	1, 9, 11.			
DELAWARE,	1	August.	4 to 5 p.m.								3.				
DIST. OF COLUMBIA,	1	August.	....								25.				
FLORIDA,	10	Sept.					7.	6.		13, 26.		9, 10.	11, 28.	5,	
GEORGIA,	128	March, April.	1 to 2 p.m. 3 to 4 p.m.	9, 11, 12, 24.	3, 8, 9. 19.	8, 15, 20, 21, 25, 26, 27, 28, 29.	1, 3, 4, 9, 10, 14, 20, 22, 23, 25, 27, 29.	1, 3, 9, 14, 18, 20.	2, 6, 12, 24.	3, 4, 10, 12, 13, 18.		11, 15.	5, 10.		12, 22, 24.

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months.											
				Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Illinois,	127	May.	4 to 5 p.m.	1.	27.	8, 10, 18, 20, 25.	14, 18, 19, 23, 24.	6, 8, 10, 12, 13, 14, 18, 19, 20, 22, 23, 25, 26, 27, 29, 30, 31.	2, 3, 4, 5, 8, 10, 11, 17, 18, 19, 21, 23, 29.	9, 13.	5, 14.	3, 9, 16, 18, 24, 29.	8.	6, 8, 14.	8.
Indiana,	84	May.	5 to 6 p.m.		21, 27.	4, 20, 25.	1, 16, 19, 30.	6, 9, 10, 12, 14, 18, 27, 28.	10, 11, 14, 18, 22, 25, 30.	1, 2, 4, 23, 26, 27.	12, 14, 22, 27.	3, 16, 22.	14, 15, 29.	6, 14, 28.	26.
Indian Territory,	6	May.					20, 21.	8, 25, 28.			1.				

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months. Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Iowa,	118	June.	4 to 5 p.m.		27.		6, 8, 11, 14, 18, 21, 26.	5, 8, 9, 13, 14, 18, 22, 23, 25, 30, 31.	1, 3, 5, 7, 9, 10, 11, 12, 14, 15, 17, 18, 21, 22, 24, 25, 28, 29, 30.	2, 4, 7, 8, 17, 18, 23, 26, 30.	5, 6, 18.	9, 26, 29.	8, 15, 30.	6, 10.	
Kansas,	153	May.	3 to 4 p.m.			1, 5, 10, 16.	1, 2, 4, 5, 6, 7, 13, 14, 17, 18, 19, 21, 22, 26, 27, 28, 29, 30.	6, 9, 11, 12, 13, 14, 15, 16, 18, 19, 20, 25, 27, 29, 30, 31.	5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 19, 20, 22, 26, 28.	1, 4, 10, 12, 16, 18, 19, 20, 26, 28, 31.	5, 6, 14, 15, 24, 25, 27.	1, 26, 29.		8.	

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months.											
				Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Kentucky,	26	March.	3 to 4 p.m.		12, 19.	2, 11, 25.		13, 14.	7, 17.	1, 8, 23.	20, 27.			6, 28.	10, 26.
Louisiana,	19	April.	4 to 5 p.m.		9, 10.	28.	2, 7, 8, 9, 26, 28.	12.		10.			11, 29.	8, 9, 14, 22.	
Maine,	7	July.	4 to 5 p.m.					14.		9, 16.	13.		18.		
Maryland,	16	August.	5 to 6 p.m. 6 to 7 p.m.		27.			22.	28.	3, 4, 15.	3, 10.	3.	6.		
Massachusetts,	22	July.	4 to 5 p.m.						11, 14, 30.	2, 9, 16, 21, 30.	1, 9, 22, 29.	4, 9.			
Michigan,	71	May.	5 to 6 p.m.		11.		5, 16, 18, 25.	6, 8, 10, 14, 15, 16, 25, 27, 31.	2, 4, 8, 12, 18, 19, 27.	8, 11, 12, 22, 23.	1, 3, 22, 31.	8, 16, 20, 22, 26.	3, 8, 14, 18.	11, 12.	

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months.											
				Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Minnesota,	78	July.	3 to 4 p.m.				13, 14.	2, 8, 20, 30.	5, 11, 12, 14, 16, 21, 29, 30.	1, 3, 7, 8, 11, 15, 16, 21, 28.	8, 9, 15, 19, 21, 25, 26.	9, 29.	9.	25.	
Mississippi,	49	April.	1 to 2 p.m.	11.	19.	10, 11, 12, 16, 17, 18, 20, 27, 28.	7, 12, 14, 15, 22, 25, 27, 29, 30.	1, 7, 16, 18.	16.		22.			11.	
Missouri,	156	May.	5 to 6 p.m.		11, 23, 27.	10, 11, 26, 29, 31.	1, 8, 12, 14, 18, 23, 24, 26, 29.	5, 8, 9, 11, 13, 17, 18, 19, 20, 24, 26, 28, 29, 30, 31.	1, 2, 3, 5, 8, 12, 13, 14, 15, 16, 17, 18, 20, 21, 30.	2, 3, 8, 10, 12, 13, 16, 20, 28.	8, 14, 17, 19, 29.	18, 23, 24, 26, 29.	8, 25.	5, 8, 25.	4, 9.

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months.											
				Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Nebraska,	52	June.	4 to 5 p.m.				7, 14, 25, 26, 27.	1, 5, 15, 17, 22, 23, 27.	1, 4, 5, 12, 14, 16, 20, 23, 24, 25, 26, 27.	7, 11, 13, 20, 28.	20, 25.	11, 27, 28, 29.	11.		
New Hampshire,	8	July.	11 a.m. to noon.					20.		1, 16, 25.	3.	9.	1.		
New Jersey,	12	August.	3 to 4 p.m. 5 to 6 p.m.				22.		19.	19, 29.	3, 11, 17.	12, 21.	4, 9.	23.	
New York,	67	July.	11 a.m. to noon. 1 to 2 p.m. 2 to 3 p.m. 3 to 4 p.m.		14.	20, 21.		9, 18, 22, 30.	3, 11, 13, 19, 22.	1, 2, 3, 4, 5, 7, 9, 10, 13, 16, 20, 21, 24, 25, 26, 30.	9, 12, 13, 14, 16, 21, 22.	9, 12, 17, 20, 25, 28, 30.	17.	6.	

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months. Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
North Carolina,	59	March.	4 to 5 p.m.		8, 19.	20, 25, 27.	2, 3, 7, 14, 15, 18, 20, 23, 29.	1, 12, 27.	10, 25, 30.	3, 6, 28.	2, 13, 25, 27.	8, 12, 13.	1, 12, 20.	6.	22, 24, 29.
Ohio,	92	May.	4 to 5 p.m.	9, 20.	4, 13, 14, 18, 19.	4, 20, 22, 25.	1, 11, 27.	12, 14, 21, 22, 23, 28.	2, 13, 14, 15, 16, 18, 19, 21, 24, 28.	2, 5, 7, 11, 14, 30.	1, 15, 22, 31.	8.	11, 20.	14.	20.
Pennsylvania,	61	May, August.	5 to 6 p.m.	20.		20, 22.	16, 19.	5, 10, 29.	2, 5, 6, 7, 11, 13, 17, 18, 21, 29, 30.	1, 2, 4, 5, 8, 11, 13, 26.	3, 6, 7, 10, 11, 16, 30.	4, 19, 28.	30.		6.
Rhode Island,	1	August.									30.				

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months.											
				Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
South Carolina,	57	Feb.	3 to 4 p.m.		19, 27.	10, 18, 20, 22, 23, 24, 25, 26.	6, 14, 15, 16, 18, 22, 23, 25, 29.	1, 4, 7, 13, 27.	3.	1, 5, 9.	14, 28.	10, 12, 17, 30.		7.	22.
Tennessee,	31	April.	1 to 2 p.m. 7 to 8 p.m.	22.	9, 12.	15, 20, 30.	3, 14, 18, 25, 28.	17, 24, 31.	17, 29.	30.	8, 29.			6.	10.
Texas,	73	June.	4 to 5 p.m.	26.		11, 31.	14, 15, 18, 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30.	2, 5, 17, 26, 28.	2, 8, 9, 10, 12, 16, 19, 22, 24, 26.	11, 12, 28, 29.	15, 18, 23, 24.			5, 6.	
Vermont,	4	July.						10.		14, 30.	9.				

Table No. 21.—Continued.

STATE.	Total No. of Tornadoes.	Month of greatest frequency.	Hour of greatest frequency.	Dates of Occurrence, Considered by Months. Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Virginia,	18	July.				4, 19.		16.	21, 25.	13, 18, 23, 27.	23, 25.	12.			
West Virginia,	2	Apl, Jun.					16.		13.						
Wisconsin,	59	July.	4 to 5 p.m.			10.	18.	9, 18, 23, 25, 31.	4, 7, 11, 17, 29.	3, 5, 7, 8, 10, 16, 22, 23, 24, 25, 29, 30, 31.	2, 3, 11, 16, 20, 21, 22, 28.	9, 20, 29.	8.	25.	

Table No. 22.

TABLE SHOWING THE RELATION OF THE OCCURRENCE OF TORNADOES TO THE ACREAGE OF FORESTS and CULTIVATED LANDS, BY STATES.

State.	Tornado records from	Number of tornadoes.	Area of States in square miles.	Number of acres of forest land according to the 10th census of the U.S., 1880.	Number of acres of cleared land according to the 10th census of the U.S., 1880.
Alabama,	1823 to 1886	102	51,540	10,430,727	22,554,873
Arkansas,	1840 to 1886	34	53,045	7,861,409	26,087,391
Colorado,	1877 to 1886	4	103,645	44,117	66,288,683
Connecticut,	1682 to 1886	13	4,845	646,673	2,454,127
Dakota Territory,	1875 to 1886	46	147,700	80,264	94,447,736
Delaware,	1885 to 1886	1	1,960	279,099	975,301
Florida,	1875 to 1886	10	54,240	2,186,601	32,526,999
Georgia,	1795 to 1886	128	58,980	15,269,225	22,477,975
Illinois,	1835 to 1886	127	56,000	4,935,575	30,904,792
Indiana,	1818 to 1886	84	35,901	5,935,308	16,946,092
Iowa,	1837 to 1886	118	55,475	2,755,290	32,748,710
Kansas,	1859 to 1886	153	81,700	991,187	51,296,813
Kentucky,	1848 to 1886	26	40,000	10,106,072	15,493,928
Louisiana,	1869 to 1886	19	45,420	4,557,332	24,500,468
Maine,	1860 to 1886	7	29,895	2,682,296	16,450,604
Maryland,	1833 to 1886	16	11,124	1,634,019	5,119,831
Massachusetts,	1821 to 1886	22	8,040	1,004,099	3,359,979
Michigan,	1823 to 1886	71	57,524	4,452,265	32,302,935
Minnesota,	1855 to 1886	78	72,205	2,030,726	48,660,475
Mississippi,	1823 to 1886	49	46,340	9,144,323	20,513,277
Missouri,	1814 to 1886	156	68,735	10,137,790	33,852,610
Nebraska,	1871 to 1886	52	76,185	321,566	48,436,844
New Hampshire,	1807 to 1886	8	9,005	1,296,529	4,466,671
New Jersey,	1822 to 1886	12	7,455	708,092	4,063,108
New York,	1787 to 1886	67	47,620	5,195,795	25,281,005
North Carolina,	1826 to 1886	59	48,580	13,868,086	17,223,114
Ohio,	1804 to 1886	92	40,760	5,982,507	20,103,893
Pennsylvania,	1811 to 1886	61	44,985	5,810,331	22,980,069
Rhode Island,	1838 to 1886	1	1,085	182,666	511,734
South Carolina,	1761 to 1886	57	30,170	7,255,121	12,053,679
Tennessee,	1808 to 1886	31	41,750	11,232,876	15,447,124
Texas,	1853 to 1886	73	262,290	15,851,365	152,014,235
Vermont,	1829 to 1886	4	9,135	1,503,467	4,342,933
Virginia,	1816 to 1886	18	40,150	9,126,601	16,553,399
West Virginia,	1838 to 1886	2	24,645	6,180,350	9,592,450
Wisconsin,	1843 to 1886	59	54,450	4,768,046	30,079,954

Table No. 23.

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
			HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.																									
Jan.	ALABAMA.	9	1	1								1		2		1		1										
Feb.		13				1	2		2	1				1		1			1									
Mar.		27						1	2	1	1	1	2	2	3		1	2							1			
Apr.		21			1					2	1	2	1			1		2	1									
May		9			1								1	1	2				1									
Nov.		9									1		1		1		2		2									
Dec.		5																	1									
	Total 93.																										42	102
Mar.	ARKANSAS	2							1			1																
Apr.		12							2		1			2	3	1			1									
May		9									1		2				1											
June		2																			1							
July		3												1		1												
Oct.		1											1															
Nov.		4								1		1											1					
	Total 33.																										11	34
May	COLORADO	2						1		1																		
June		2								1	1																	
	Total 4.																											4
May	CONN.	1							1																			
June		2								1	1																	
July		3					1					1	1															
Aug.		3								1				1														
Sept.		2												1														
Oct.		1												1														
	Total 12.																										3	13

Table No. 23—continued.

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
			HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.																									
Apr.	DAKOTA	5									1																	
May		2					1								1													
June		8							1				2	1														
July		14	1		1				2	1	2	1	2	3														
Aug.		11									1	1	1	3	1													
Sept.		4										1		1	1													
	Total 44.											1															16	46
Aug.	DEL.	1										1																
	Total 1.																											1
July	FLORIDA	2									1			1														
Sept.		3														1		1										
Oct.		2					1																					
Nov.		1							1																			
	Total 8.																										4	10
Jan.	GEORGIA	4											1						1		1							
Feb.		27						3	4	3	4		4	5	3					1								
Mar.		30				2	1	3	3	1	3	3	2		1		1		1	1	1							
Apr.		30						1	1	1	2		1	1	3	1					2	1	2	1	1			
May		8							1		1		1	1		1												
June		4			1	1						1																
July		7								1		1																
Dec.		5				1			1										1									
	Total 115.																										42	128

Table No. 23—continued.

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
			HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.																									
Jan.	ILLINOIS	1								1																		
Feb.		1								1																		
Mar.		6								1			1	2									1					
Apr.		15								1			2	2	1		1				1			1				
May		50							2	2	3	4	13	9	3	3	5	1		1								
June		19								1		5	2			1												
July		4													2													
Aug.		5										1	1		1													
Sept.		15				1					5	4	1		1													
Nov.		6					1	1			1	2	1															
Dec.		1			1																							
	Total 123.																										32	127
Feb.	INDIANA	2									1																	
Mar.		7									1	3	2					1										
Apr.		6									1	2		1														
May		25							2		1	3	4	2	3	1	2											
June		13							1			1	1	1	1	2												
July		9			1					1			2															
Aug.		7									1	1	1			1												
Sept.		6					2				1					1												
Oct.		3				1									1													
Nov.		4																										
Dec.		1											1															
	Total 83.																										28	84
Apr.	INDIAN T.	2															1			1								
May		3												1														
Aug.		1																								1		
	Total 6.																										2	6

Table No. 23 —continued.

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
			HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.																									
Feb.	Iowa	2						1	1																			
Apr.	Iowa	31								2	6	7	2	2	2	3					1				1			
May	Iowa	18						2	1	1	3	2		1			2	1										
June	Iowa	37					1		1	1	6	5	3	3		2	1	1	1					1	1	1		
July	Iowa	15										3	4	2		1												
Aug.	Iowa	3								2																		
Sept.	Iowa	3										1																
Oct.	Iowa	6									2	1	1															
	Total 115.																										33	118
Mar.	Kansas	4										2																
Apr.	Kansas	30						1	1		6	3	4	1		1		1	1		1							
May	Kansas	45			1	3	3	2	1	4	8	3	7	1									1					
June	Kansas	40								4	5	5	2					1	1	1		1						
July	Kansas	18			2					1	1	5	1		2	1												
Aug.	Kansas	8				1			1	1	1							1										
Sept.	Kansas	7									1		2	1														
	Total 152.																										55	153
Feb.	Kentucky	3							1					1														
Mar.	Kentucky	6								1	3	1																
May	Kentucky	3											1			1							1					
June	Kentucky	2								1													1					
July	Kentucky	3											1															
Aug.	Kentucky	2																	1									
Nov.	Kentucky	2									1														1			
Dec.	Kentucky	2									1																	
	Total 23.																										9	26

Table No. 23—continued.

Month	State.	Total Number by months.	HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD. 7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
Feb.	LOUISIANA	2										1											1					
Apr.		7									1	1		1														
July		1												1														
Oct.		2																			1							
Nov.		5										2	1															
	Total 17.																										9	19
July	MAINE	4										3																
Aug.		1										1																
Oct.		1				1																						
	Total 6.																										2	7
Feb.	MARYL'D	1												1														
May		1												1														
July		4													1													
Aug.		6					1				1		2	1														
Sept.		1											1															
Oct.		1									1																	
	Total 14.																										7	14
June	MASS.	3								1		1																
July		9								2	1	2	1															
Aug.		5									1	1	1															
Sept.		2											1															
	Total 19.																										10	22
Apr.	MICHIGAN	11										1	3	2	1		1											
May		14							2	1	3	1		1			1	2										
June		8							1				2						1		1							
July		7					1				1								1									
Aug.		6			3							2	1															
Sept.		15					2	5	1			1																
Oct.		4							1																			
Nov.		2										1																
	Total 67.																										28	71

Table No. 23—continued.

Month	State.	Total Number by months.	HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.																								Total No., month and hour not recorded.	Total number of Tornadoes observed.
			7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.		
Apr.	MINN.	16								1	8	2		1														
May		4																	1									
June		15							3		1	1			1	1												
July		20					1		2	1	2	3	2	1					2									
Aug.		17			1					1		3	1	1	3													
Sept.		3										1																
Oct.		1					1																					
	Total 76.																										42	78
Jan.	MISS.	1										1																
Feb.		2				1																						
Mar.		15					1	1	2	1	1		1	1		2				1								
Apr.		19				1		2	3	2	1	1				1					1							
May		8							1																			
	Total 45.																										23	49
Feb.	MISSOURI	4								1	1	1																
Mar.		5								1	2	1				1												
Apr.		32	1				1		1			5	7		3	3		1					1		1			
May		42					4	2		2	1	4	4	2	3	5	1					1						
June		29				1				2	2	3	2	3	1	1	2											
July		13		1			1	1	1		4		1															
Aug.		5						1					2															
Sept.		8								1	1		2															
Oct.		2						1								1												
Nov.		6								2		1																
Dec.		6									1				3		1											
	Total 152.																										52	156

Table No. 23—continued

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
			HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.																									
Apr.	NEBRASKA	8									3	1		1														
May	NEBRASKA	11								2		1	2	1														
June	NEBRASKA	18							1		2	3		1				1							1			
July	NEBRASKA	6							1		1	1		1												1		
Aug.	NEBRASKA	2																					1					
Sept.	NEBRASKA	6					1					1				1		1										
Oct.	NEBRASKA	1													1													
	Total 52.																										21	52
July	N. HAMP.	4					2																					
Sept.	N. HAMP.	1											1															
	Total 5.																										5	8
Apr.	N. JERSEY	1									1																	
June	N. JERSEY	1											1															
July	N. JERSEY	2								1																		
Aug.	N. JERSEY	3									1																	
Sept.	N. JERSEY	2											1															
Oct.	N. JERSEY	2							1																			
	Total 11.																										6	12
Mar.	NEW YORK	2							1																			
May	NEW YORK	5							1	2																		
June	NEW YORK	8									1	1	1									1						
July	NEW YORK	28					5	1	3	2	1		1		1													
Aug.	NEW YORK	9									2	2																
Sept.	NEW YORK	7								1		1	1	1														
Oct.	NEW YORK	1														1												
Nov.	NEW YORK	1									1																	
	Total 61.																										35	67

Table No. 23—continued.

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
			HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.																									
Feb.		8												2	2	1	1	1								1		
Mar.		14				1				1	1	4		1				2	1									
Apr.		11										1			1											1		
May		3					1				1			1														
June		3									1					1												
July	North Carolina	3								1			2															
Aug.		4															1											
Sept.		4										1														1		
Oct.		4									1		1															
Nov.		1					1																					
Dec.		3											1			1												
	Total 58.																										18	59
Jan.		2							1																			
Feb.		6										1																
Mar.		6									2					1	1		1									
Apr.		6										2				1												
May		32							1	1		1	2	1	1	2	6	9	3									
June	Ohio	15								1		3	1	1	2		2											
July		9				1				1	1	1										1	1					
Aug.		6			1					2																		
Sept.		4												2	1			1										
Oct.		2																				1						
Nov.		1				1																						
	Total 89.																										31	92
Mar.		3									1			1														
Apr.		2									1																	
May		13									2	2	7															
June		12		1									1		1						1							
July	Penna.	9					1	1		1	1					1												
Aug.		13					1			1	2	1	1															
Spet.		4								1	1		1															
Dec.		1											1															
	Total 57.																										28	61

Table No. 23—continued.

HOUR OF OCCURRENCE. NUMBER OF TORNADOES IN EACH PERIOD.

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
Aug.	RHODE IS.	1									1																	
	Total 1.																											1
Feb.	SOUTH CAROLINA	13					1				3		3	2	1		1	2										
Mar.		11									2	2	3	1				1						1				
Apr.		12									4	1		2														
May		6								2		1		1														
July		4								1		1																
Sept.		4						1		1		1																
Nov.		1			1																							
Dec.		1										1																
	Total 52.																										16	57
Feb.	TENN.	3															1	1										
Apr.		10													2	1		1										
May		4							1						1													
June		3												1														
July		1											1															
Aug.		3							1		1			1														
Nov.		1							1																			
	Total 25.																										15	27
Jan.	TEXAS	2														1												
Mar.		4									1	1			1													
Apr.		22			2			3	2	2		1	3	1			1	2			1	1						
May		8			1									1	1		1											
June		26	1		1						4	6.	2	3	4													
Aug.		5									1					1												
Nov.		2										1																
	Total 69.																										22	73
July	VERMONT	2											1															
Aug.		1										1																
	Total 3.																										2	4

Table No. 23—continued.

Month	State.	Total Number by months.	7 to 8 a. m.	8 to 9 a. m.	9 to 10 a. m.	10 to 11 a. m.	11 to 12 m.	12 to 1 p. m.	1 to 2 p. m.	2 to 3 p. m.	3 to 4 p. m.	4 to 5 p. m.	5 to 6 p. m.	6 to 7 p. m.	7 to 8 p. m.	8 to 9 p. m.	9 to 10 p. m.	10 to 11 p. m.	11 to Midn.	12 to 1 a. m.	1 to 2 a. m.	2 to 3 a. m.	3 to 4 a. m.	4 to 5 a. m.	5 to 6 a. m.	6 to 7 a. m.	Total No., month and hour not recorded.	Total number of Tornadoes observed.
Mar.	VIRGINIA	2																				1						
Sept.		3							1		1				1													
	Total 5.																										15	18
June	WEST VA. Total 1.	1										1															1	2
Mar.	WISCONSIN	1										1																
Apr.		2										2																
May		7									1	1		1														
June		8						1			1	1	1															
July		19					1	2	1	3	2				1	2					1							
Aug.		13					1		1	1	1	2	1	1		1												
Sept.		5										2		1			1											
Oct.		2					1																					
Nov.		1														1												
	Total 58.																										21	59
Aug.	DIST. COL. Total 1.	1																									1	1
	Totals	1761																									685	1,867

RESULTS FROM TORNADO RECORDS OF 205 YEARS.

1. The rotary movement of the whirling tornado-cloud is in five hundred and twenty cases reported as against the hands of a clock, and twenty-nine cases as probably moving with the hands of a clock.

2. Electrical discharges were observed in two hundred and fifty-two cases as occurrring in the clouds surrounding the tornado-cloud; that is, in the clouds near the horizon: and in eighty-four cases as occurring in the funnel cloud.

3. The width of the path of destruction, supposed to embrace the distance between the areas of sensible winds on the two sides of the tornado-cloud, varied in 1,167 cases from 10 to 10,560 feet, the average being 1,369 feet.

4. The length of the tornado's track, as reported in 385 cases, varied from 300 yards to 300 miles, the average being 24.79 miles.

5. The velocity of progression of the tornado-cloud, as determined from the reports in 201 cases, varied from seven to 100 miles per hour, the average being 44.13 miles.

6. The shortest time occupied by the tornado-cloud in passing a given point, varied from "an instant" to about twenty minutes; the average being about seventy-four seconds.

7. The occurrence of thunder-storms in relation to tornadoes is reported upon as follows: In 287 cases they occurred before the tornado-cloud appeared; in 113 cases, accompanying the tornado-cloud; in 57 cases, after the disappearance of the cloud, and in eight cases their entire absence was noted.

8. Concerning the time of occurrence of the tornadoes, the hours of greatest frequency are found to be from 3:30 to 4:00 P. M. and from 4:30 to 5:00 P. M.

9. The State in which the greatest number of tornadoes occurred is Missouri, followed next in order by Kansas and Georgia.

10. The month in which the largest number of tornadoes occurred is May, followed next in order by April and June.

11. The month of greatest frequency, that is, the month embracing the largest number of days on which tornadoes occurred, is May.

12. The prevailing direction of progressive movement of the tornado-cloud is northeast.

13. Of 990 cases where the time of rain was recorded, 377 reported precipitation as preceding the tornado; 437 as following it; and 176 as accompanying it.

14. Of 604 cases where the time of hail was recorded, 317 reported the precipitation as preceding the tornado; 124 as following it; and 163 as accompanying it.

A SCIENTIFIC RÉSUMÉ OF TORNADO CHARACTERISTICS.

What follows under the head of "Scientific Résumé of Tornado Characteristics," was prepared for a special purpose after much investigation and careful study.

What is called the "Electrical Origin of Tornadoes," and all violent local storms of a similar character, is not of recent designation. Certain French scientists, foremost of whom probably stands M. Peltier, whose first writings on this subject appeared in 1839, have asserted that all the usual phenomena which combine to form whirlwinds are the direct result of electricity.

In about 1860, M. De Fonville, a member of the French Academy of Sciences, discussed the electrical origin of storms. The electrical theory has found many followers in America, probably the most prominent in a sensational way being Prof. Tice, the "Weather Prophet," of St. Louis, now deceased.

On the 10th of June, 1879, a terrific storm of wind, rain, and hail, moving from northwest to southeast, passed over Ottawa Co., Kansas, nearly destroying the town of Delphos in that county. Thirty-seven buildings were torn to pieces and sixteen persons seriously injured. I visited the town a few days after the storm and made a careful examination of its path and the destructive effects. Prof. Tice heard of this storm through the newspapers, and, in support of his theory, published in the *Cincinnati Inquirer* of June 5th, 1880, a long article, from which the following extracts are taken :—

I hold that electricity is the cause of all meteorological phenomena, winds of every kind, cyclones, cloud formation, rain, hail, and snow.

Railroad and telegraph lines obey the laws of induction and give rise to the necessary electric changes to produce storms.

Have the following facts any significance? Delphos, in Ottawa Co., Kansas, is situated on the east bank of the Solomon River, and is a station on the Solomon Valley Railroad.

A tornado on May 30th, 1879, destroyed the railroad depot and many houses. The town was visited by a second and very destructive tornado on the 6th of June, that is two tornadoes in eight days.

In this hasty attempt to bolster up a theory the calculation missed its aim through discrepancies in the facts as follows:

1st. The tornado of May 30th, 1879, passed eastward three miles southeast of Delphos without producing the slighest injury in the town.

2d. The storm which struck Delphos occurred June 10th, and not June 6th.

3d. There was no railroad at Delphos, no railroad buildings, and no telegraph lines, but the people were trying to raise the funds to obtain such conveniences by extending the track, which then terminated at Minneapolis, about twenty miles distant.

In 1879, '80, and' 81 the question of the electrical origin of wind-storms came before the courts of certain States, principally Wisconsin, Missouri and Kansas, in the interest of insurance claimants. Certain parties who were policy-holders had their property (which was insured against lightning) destroyed by wind-storms, and brought suit for recovery against the insurance companies on the ground that, both in the popular acceptation of the term and in its true scientific meaning, lightning or electricity was the cause of all violent wind-storms. This theory the policy-holders tried to maintain by every possible means, and in the course of the struggle I was summoned to appear before the courts as a scientific expert on the question of the origin and development of tornadoes. I made special preparation for the engagement, and took occasion to embody the results of my labors in the form in which they here appear under the heading of "Scientific Résumé of Tornado Characteristics."

In regard to the electrical origin of tornadoes, I take pleasure in quoting from the pen of Prof. James C. Watson, the great astronomer and physicist, who at the time of making this statement was director of Washburn Observatory, Madison, Wis., and on the witness stand in one of the above cases. He says: "I think that all science that is science, proves absolutely that the effect could not have been produced by lightning. The force of the tornado cannot be explained on the theory of electric action; it is utterly impossible, inconceivable, and contrary to every well-established law of electricity."

A SCIENTIFIC RÉSUMÉ OF TORNADO CHARACTERISTICS.

1. The forces of the tornado-cloud are active and continuous while the phenomenon exists.
2. They are exerted successively, uninterruptedly, and always in the same general directions.
3. The forces appear to be uniform.
4. The forces are not apparently diminished by having to destroy a succession of the heaviest and strongest structures.
5. The forces are not affected by having to meet with, in rapid succession, totally different objects—different in size, strength, shape, materials, composition and structure, relative position, etc., etc.
6. The forces are exerted continuously over a breadth of surface varying from 50 to 600 yards.
7. The forces are exerted continuously for distances varying from five to 200 miles.
8. The characteristics of the tornado-cloud are constant, and all of its features and mode of development show it to be a windstorm, simply.
9. When the cloud disappears, it does so from the earth upwards, its action evidently depending upon forces in the upper regions of the atmosphere.
10. The time of day, the time of year, and the peculiar hot and stifling condition of the atmosphere indicate that heat is the physical agent developing the tornado.

11. The tornado is invariably accompanied by hail, which is evidently not of electrical formation.

12. Electricity is simply an accompaniment of the tornado, as is the hail, and not the primary cause.

13. The cloud is almost invariably funnel-shaped, with the small end nearest the earth. The resistance of the atmosphere is less at higher altitudes because of less density, consequently the cloud spreads out at the top.

14. The tornado-cloud always has a rotary motion, from right to left.

15. It moves in a certain direction, S.W. to N. E., without regard to obstacles.

16. The tornado-cloud is generally impenetrable to vision, and is sometimes dark, like coal smoke, and then again white, like steam.

17. The contrast between the white, steam-like appearance of the tornado-cloud and the surrounding dark clouds gives rise to the semblance of fire, and the cloud appears illuminated.

18. What is called lightning by the frightened observers is never seen by them when the tornado-cloud is observed in advance of the dark clouds to the westward and surrounded by a clear sky.

19. What is termed the "smell of sulphur" is simply ozone in the air, which nearly always appears after a thunder-storm.

20. It is to be noted that a calm, cool observer rarely reports the appearance of lightning in the tornado-cloud proper.

21. It is to be noted that lightning is always observed *before* and *after* the tornado-cloud appears, but in the heavy, dark clouds far to the west, north, and northeast of the tornado cloud.

22. Observers are nearly always mistaken about the distance of the flash of lightning. Light travels with inconceivable rapidity, so does the electric fluid, and the electric flash is of intense brilliancy, consequently lightning appears much nearer to the observer than it really is.

23. Observers can really give no reason for their belief that electricity is the cause of the tornado, but almost invariably reply to the question, "that if electricity is not the cause, they have no idea what could produce such a terrible force."

24. From an examination of a great many witnesses it is evident that the reason for belief in electricity as the cause is the sudden, awful, irresistible, and terribly destructive force of the tornado. It is of the air, wild and majestic, yet mysterious.

25. Many witnesses at first report the lightning as appearing in the tornado-cloud, and then after careful thought remember that the flashes were really from clouds far beyond the tornado-cloud.

26. Almost invariably the observer is so placed that the tornado-cloud is between him and the dark, threatening clouds to the westward, so that in the excitement of the occasion he cannot distinguish the exact location of the source.

27. In the tornado's track the débris is always carried in the direction of the moving force, frequently in the arc of and sometimes entirely throughout a circle. This is not a peculiarity of electric force.

28. Heavy and light objects are transported long distances, the latter sometimes 50 miles.

29. Objects that are carried long distances are always transported to the east or northeast, and evidently by air-currents.

30. Objects carried long distances are frequently found uninjured.

31. Vegetation is withered by the action of the sun's heat in evaporating the fluids from the leaves and buds that have been broken and bruised by the whirling action of the air in the tornado-cloud. The evaporation drys and withers the foliage, and it looks seared.

32. Where the bark of trees has been chipped off or loosened in places the sap appears and is evaporated by the action of the sun's heat, and as a result the tender surface of the exposed portion of the body of the tree is turned black.

33. No ordinary wind or hardly a heavy, straight wind is able to so whip the foliage of trees, or the leaves of grain and plants, as to cause them to wither and appear scorched. It requires the rapid, peculiar, and irresistible rotary action of the air in a tornado to accomplish this result.

34. The energy of the tornado is exhibited with no greater force in relation to metals than in relation to other substances.

35. The force of the tornado-cloud is not measured any respect by the character of the materials upon which it acts.

36. The form of an object, no matter what the size, does not control or modify or influence in any way the intensity of the tornado's force.

37. Objects are destroyed by the peculiar force of the tornado before the tornado-cloud reaches them. Trees begin to sway and are bent to the ground, and buildings and lighter objects are drawn or sucked towards the advancing cloud from all sides of it.

38. By the rotary action of the tornado-cloud the condensed vapor is whirled into a fine mist, giving it the appearance of steam, and lighting the interior of the cloud.

39. The tornado is accompanied by a rumbling noise (very peculiar), which never ceases while the funnel-shaped cloud is upon the earth or a short distance above it.

40. Timbers acted upon by the force of the tornado are often driven to considerable depths into the solid earth, sometimes to the distance of nine feet. They are sometimes driven into buildings and other pieces of timber.

41. Wherever fire is reported to have been seen in the débris of the tornado it has, upon close examination, been found that witnesses did not actually see fire (they saw light); but they saw smoke, and from that judged that fire must be present. Now, this so-called smoke is nothing but the dust and condensed vapor of the whirling tornado cloud, which envelops and penetrates every structure over which the tornado passes. This so-called smoke is often seen issuing from the doors, windows, and other openings of the house, and even out of chimneys, when fire was *known* not to have been in the house at the time.

42. The energy of the tornado-cloud is confined with in very narrow limits, the boundaries being distinguished with remarkable exactness even in the atmosphere.

43. The width of the tornado's path upon the earth's surface is probably the counterpart of the diameter of the upper or broad end of the funnel-shaped cloud.

44. In the ricochet motion of the tornado-cloud, especially as the cloud leaves the earth, the maximum destructive force is

found to be diminished, but not entirely suspended. The in-rushing air-currents are still sufficiently powerful to overturn fences, small buildings, and trees, and lift loose objects from the earth.

45. In the ricochet motion of the tornado-cloud the cloud does not dip down to the earth, although it appears to do so. There is not an actual descent of the entire body of air within which the terrible forces are at play. On the contrary, the in-rushing air-currents from the earth's surface, as they pass upward and unite with the disturbed conditions above, carry up dust and small débris, which, mingling with the condensed vapor from the rapidly rising air forms a dark cloud, and completes the connection to the eye between the upper cloud and the earth.

46. The potential and living energies of the tornado must be distinguished from the *cloud*, which simply shadows forth the limits within which these energies exist or may be called into action.

47. The so-called quiverings and contortions of the cloud are but the peculiar movements, in fantastic forms, assumed by the rapidly condensing masses of vapor.

48. The funnel form of the cloud is due to the peculiar ascensional movement of air-currents, the vapor being condensed along the central line of movement by the cold of elevation. This action would tend to form a column of cloud, the upper extremity of which would be broader than the lower, because of the overflow and spreading out of the ascending masses of air in the upper regions of the atmosphere, and also diminished resistance to the gyratory motion of the vortex.

49. The motive power of a tornado and the agency which lifts objects or carries them long distances, is that motion of the air within the cloud set up by the variable heat conditions of large masses of air over adjacent regions.

50. The violent upheaval of a small column of air forms a vortex along the central line of movement within which the power of pressure against all resistance is often greater than one atmosphere.

51. The tornado vortex may be formed either by an ascensional movement of a mass of heated air, giving rise to unstable

equilibrium, or by the meeting of opposite currents with high-temperature gradients, or by a combination of both of these meteorological conditions.

52. Two currents of air approaching each other from opposite directions will not come directly together, because of the influence of the relative motion of the earth. The mass of air coming from the south would have a greater velocity eastward than that coming from the north. Therefore, instead of meeting each other in a direct line, the two currents will form an angle at their intersection, and the combination of the two masses will give rise to a rotation in a direction contrary to the hands of a watch with its face upwards. These conditions account for the spiral movement of the air-currents and the formation of the vortex in the tornado. The cold air from the northward will under-run the warmer air from the southward, because of the difference in density of the two masses, and as a result will aid in the formation of the whirl.

53. The tornado vortex cannot remain stationary on the surface of the rotating earth, but must, by well-known dynamical laws, move bodily in a direction the resultant of the opposing forces in its formation.

54. The tornado vortex will have a tendency to drift with any strongly prevailing current of air.

55. The tornado vortex may be very whimsical in short movements, owing to the extreme elasticity of air and the mobility of its particles.

56. After carefully reading my various papers on the subject of tornadoes, H. H. Rowland, Professor of Physics, Johns Hopkins University, Baltimore, says: "It becomes apparent that *if* electricity has anything to do with the development of a tornado, it is *not* with the tornado-cloud itself *after it has formed* and the tornado is advancing over its path of destruction, but with the *two clouds* which *attend* the *formation* of the tornado."

57. All of the phenomena of a tornado cannot be accounted for on the supposition of opposite electrification of two clouds.

58. According to Sir William Thomson, the electrostatic tension of air is only equal to a pressure of 68 grammes per square

decimetre, or one fifteen-thousandth of the pressure of one atmosphere.

59. There is no fact in observation or in electrical science to prove that clouds, under any conditions, actually move about in the atmosphere through the agency of opposite electricities or electrical attraction.

60. In the incipient stages of a tornado, observers always speak of the rushing together of clouds from opposite directions. This is a very natural and necessary effect in the development of a vortex. It is the air-currents (set in motion by contrary heat conditions) which cause the clouds to move, and not electrical attraction.

61. There is no distinction between the movements of air masses under the most ordinary atmospheric conditions and those under which they move in the tornado, except in intensity.

62. If electrical attraction is the cause of air-motion in a tornado, it is the cause of any and all atmospheric movements, however feeble or mighty. But this remarkable position no physicist contends for a moment.

63. The electrical tension of the air cannot under the most favorable atmospheric conditions cause the movement of oppositely electrified air masses, because of the excellent conductivity of free air, which always tends to equalize electrical potential.

64. In a mass of air or cloud having an altitude of one mile, a diameter of one mile, and a thickness of one-tenth of a mile, the electro-motive power can never exceed 68 grammes per square decimetre. Converted into English measures this expression denotes a pressure of 1,049.3964 grains upon an area exposing a surface of 15.5006 square inches. At this rate the electromotive force of the entire mass of air or cloud would be about 17,000,000 kilogrammes, or 37,478,561.25 pounds a voirdupois. The weight of this large mass of air or cloud is about 500,000,000 kilogrammes, or 1,102,310,625 pounds avoirdupois. Now, the square root of the ratio of the mass to the force is about 5; hence, the velocity of motion required by the mass in moving any distance will be five times less than the velocity of a body falling the same distance under the action of gravity. Under these circumstances the velocity acquired by the mass in passing

over a mile will be about seventy miles per hour. Two such masses of air or cloud coming from opposite directions would thus approach each other at the rate of 140 miles per hour. But this is the velocity of movement of the two masses in free space, which condition never actually exists. Under natural circumstances the electro-motive force of the opposing masses would not only have to move each mass as a whole, but the entire atmosphere around them. Furthermore, the extreme of electrical force, under the most favorable circumstances, has been assumed. Returning to the numerical expressions of force we find that the work done by 17,000,000 kilogrammes over a distance, for example, of 2,000 inches is 34,000,000,000 kilogrammemetres or 68,000,000,000 kilogrammemetres in both, which is equivalent to about 200,000,000 foot tons of work. This quantity of work would cause a cylinder of air 2,640 feet high and 1,320 feet in diameter to make 400 revolutions per hour. At the circumference the motion would reach a velocity of about 300 miles per hour, decreasing towards the center. In this rough calculation the most advantageous circumstances have been assumed, and it is not to be supposed for an instant that these conditions ever exist in the manner estimated.

65. Assuming variability of heat conditions as the source of energy in the tornado, we may derive a force which is sometimes 500 times as great as the measure of one atmosphere, while the force due to electricity can never exceed more than one fifteen-thousandth of the same pressure.

66. A column of heated air, ascending and drawing in air from the surrounding regions, would very quickly develop a rotation possessing an energy which might be tens, and even hundreds of times, in excess of that due to electricity. Similar results would follow in case of differently heated masses of air approaching each other from opposite directions.

67. If the forces of a tornado are of electrical origin, the tornado once formed must gradually decrease in power and motion as it advances. But if the theory of heated air is conformable to truth, the tornado may augment in intensity after formation. In other words, if the origin is electrical, the maximum power of the tornado is reached at once; if calorific, the maximum

power is attained gradually and by successive steps. It is not difficult to realize that the results of all observation and investigation support the theory of heated air as the source of tornadic action.

68. All observation and investigation point to the fact that the development of a tornado is gradual. It is not ushered into complete existence at the beginning. When the tornado vortex reaches the earth the extreme violence of the storm is accomplished, and this intensity continues undiminished while the cloud remains upon the surface. It frequently happens that the tornado vortex is observed to form by the coalescence of several smaller vortices which play about the central whirl with varying form and intensity.

69. The larger the volume of air (within vertical limits) embraced by the vortex the more destructive the tornado's violence. Therefore, as the vortex descends from the lofty regions of its inception, its aggregate energy is constantly increasing until it reaches the earth.

70. The greater the elevation of the vortex above the earth, the greater the mass of intervening air to overcome and the smaller the volume engaged in the production of energy; consequently, the frequently observed intermissions of energy in the tornado's path. This intermission does not mean total absence of force, but only a diminution of the maximum power.

71. Owing to the great centrifugal forces of the tornado-cloud the center of the vortex must very nearly approach the condition of a vacuum.

72. The opportunities for the formation of a tornado vortex in the upper regions of the atmosphere are greater than near the earth's surface, the density of the air increasing as you descend, making the resistance to motion in that medium inversely as the altitude.

73. After the vortex has once formed, it readily descends to the earth by drawing in the air from beneath it as well as from either side. Thus the contact of air masses of different temperatures is secured, rapid condensation follows, and the funnel-shaped cloud is soon formed.

74. As the vertical action of the air becomes intensified, its power to overcome resistance is multiplied, and the descent of the vortex continues. At the earth's surface it overcomes all resistance, and the dread hour-glass form of the tornado-cloud soon appears.

75. A tornado is that condition of the atmosphere which gives rise to the development and maintenance of a vortex, whose outward visible fashion or figure is a funnel-shaped cloud that revolves about a vertical axis from right to left.

76. The origin of a tornado is calorific; that is, the phenomenon results from high-temperature gradients existing in adjacent air masses.

77. The concomitants of the tornado are an oppressive or sultry condition of the air. The gradual setting in and prolonged opposition of northerly and southerly air-currents over a considerable area. A gradual, but continued, fall of the thermometer, with a prevalence of the northerly currents, and a *rise* with the predominance of the southerly. Decided temperature gradients across the line of progressive movement to the northwest and southeast. Huge masses of dark and portentous clouds in the northwest and southwest, possessing a remarkable intensity of color, usually a deep green.—A remarkable rolling and tumbling of the clouds, scuds darting from all points of the compass towards a common center.—Hail and rain accompany the tornado, the former either in unusual size, form, or quantity, and the latter either in remarkable quantity or size of drops. The presence of ozone is usually detected in the wake of the tornado.—A remarkable roaring noise, like the passage of many railroad trains through a tunnel. The clouds generated by the vortex assume the form of a funnel with the smallest end towards the earth.—The vortex has four motions, viz.: 1st, the whirling or gyratory motion, always from right to left; 2d, the progressive motion, generally from some point in the southwest quadrant to some point in the northeast quadrant; 3d, the ricochet motion; 4th, the oscillatory motion.—The remarkable contraction of the storm's path. The remarkable definiteness of the limits of the storm's path. Upon reaching the earth's surface the vortex assumes the form of an hour-glass.

78. The characteristic effects of a tornado are: Objects are drawn towards the vortex from every point of the compass. Objects passing into the vortex are thrown upward and outward by the vortical action of the engaged air. Structures are literally torn to pieces by the vortical action of the atmosphere, evidence of which is afforded both by the fineness of the débris and also its disposition in the storm's path. The débris is thrown inward from either edge of the storm's path. Light objects are carried to great heights and also great distances. Objects are carried inward and upward by the centripetal action of the vortex, and outward by the centrifugal force. Weight and size are conditions which present immaterial values to the power of the tornado. People are stripped of clothing. Fowls and birds denuded of feathers. Trees are whipped to bare poles. Long and heavy timbers are driven to considerable depths in the solid earth. The vortex is completely filled with flying débris. Timbers are driven through the sides of buildings. Sand and gravel are driven into wood. Human beings and animals are run through with splinters and timbers. Straws, bits of glass, and pieces of metal are driven into wood. The strongest trees are uprooted or twisted off near the roots. People and animals are terribly mangled by the force of the wind and by contact with flying débris. In the path of the storm all vegetation is destroyed. Railroad trains are thrown from the track. Iron bridges are completely dismantled and carried from their foundations. Heavy boulders, weighing tons, are rolled along the earth. The largest railroad engines are lifted from the tracks.

79. All objects, whether metal or non-metallic, magnetic or non-magnetic, simple or compound, animate or inanimate, are acted upon and with in a similar manner.

80. Every effect is the result of ordinary mechanical motion with varying degrees of intensity.

81. If it were possible to revolve a mass of air (similar to that engaged in the tornado's vortex) with enormous velocity by mechanical means, the characteristic violence of the tornado would follow.

82. The motive power of the tornado is not and cannot be electrical while our atmosphere remains in in its normal condition.

83. The peculiar roaring noise which accompanies the progress of the tornado cannot be ascribed to the intervention of electrical forces. Within the range of observation and experiment nothing has been brought to light in electrical science which will authenticate such a statement. It is far more reasonable to assert that the noise is produced by the resistance which the rapid and violent indraughts of air encounter while passing into the tornado's vortex. The vortex approximates a vacuum, and the air rushes into it at the spout end near the earth with great violence, attended by a hollow, sucking sound of marked intensity.

84. All sound is vibration and the sonorous body may sometimes be air. In the tornado it is a vast column of gyrating air, within close confines, whose vibrations are propagated through the surrounding masses of air (not partaking of gyratory action) in every direction.

85. In passing through a body of timber or during the destruction of buildings the roar of the storm increases because the sources of sound are augmented; there is a greater number of sonorous bodies set in vibration; the vast and varied mass of flying débris furnish a multitude of vibrating centers of variable degrees of intensity, and the commingling and confused succession of sounds produce an interminable roar.

86. The only possible method for electrical force to effect the formation of the tornado, would be by some (as yet unknown) relation of physical agencies to set the air in motion and keep it in motion (a motion of the most terrific violence) for several hours. But this result cannot be reached owing to the extremely low electrical tension of the air. If it were possible, however, wind would still be the immediate agent of destruction and not electricity.

87. If electricity enters as the fundamental cause into the origin of the tornado, it must act likewise throughout the entire category of atmospheric disturbance. If so, then, all wind (air in motion), however feeble or violent, is of electrical origin. But this conclusion leads to an impossibility.

88. It is simply absurd to suppose, and much worse to insist, that electricity directly, by its attractive and repellant forces, produces the destruction in the wake of the tornado.

89. If, however, electricity does not act in the manner here described, its intervention could only be effected by supposing that the whirling masses of clouds and air were in some indescribable method exerting the power of magnets.

90. A magnet, however powerful, will only manifest its force in the presence of magnetic bodies or bodies that are capable of being magnetized.

91. In the tornado, however, all objects receive the violence of the storm irrespective of magnetic properties.

92. It is claimed that no disruptive discharge of electricity takes place during the ascensional movement of débris in the tornado vortex. If so, what produces the so-called electrical displays in the cloud?

93. How does lightning appear in the tornado-cloud? Electric flashes cannot form except by a disruptive discharge. Can it be explained by saying that part of the electrical force is expended in flashes and the remainder in moving objects upon the earth? Such results would necessitate the existence of an infinite supply of atmospheric electricity. There is no evidence of any such quantity in the air or the possibility of producing it through the intervention of natural agencies.

94. There is no fact or record to show that an electrical discharge or any manifestation of atmospheric electricity ever entirely demolished a large stone or frame building; ever carried the débris of buildings for miles in the air; ever lifted a locomotive from the track; ever carried an iron bridge from its foundations and twisted the frame-work into a shapeless mass; ever rolled a boulder from its bed in the ground; ever imbedded one piece of timber into another after having carried the former for several hundred yards in the air; ever carried bedding and clothing for miles in the air; ever elevated to considerable heights in the air columns of water from ponds, lakes, and rivers; ever lifted animals from the earth and carried them over buildings; ever drew the water from a well or cistern; ever twisted a tree from its stump; ever turned a building bottom side up or end for end without otherwise injuring it. Many other effects of the peculiar manifestations of power in the tornado might be instanced to illustrate the impossibility of electrical intervention.

95. There are many effects of electrical force, decidedly characteristic, which are not within the compass of a tornado's power. This statement may be reversed with eqaul significance.

96. Lightning is the result of an extremely itensified discharge of electricity in the open air.

97. The lightning's flash is the result overcoming the electrical tension of the air at any point or succession of points.

98. The concomitants of lightning are: large accumulation of electric potential, high electrical tension, the presence o large masses of cumulo-stratus clouds, brilliant flashes and heavy detonation.

99. The effects of lightning are: rupturing and scaterring of imperfectly conducting substances and the inflaming of those which are combustible; heating, reddening, melting, and volatilization of metals; the production of shocks more or less severe and often fatal to lives of men and animals; the production of ozone, causing a sulphurous odor.

100. The cause of atmospheric electricity is not definitely known, but its existence has been ascribed to the following agencies: evaporation, the chemical processes incident to vegetable life, the friction of solid and liquid particles against the earth and against each other by the movement of air-currents.

101. By condensation, unelectrified vapor becomes an electrified liquid, and opposite electricities are developed.

102. All atmospheric phenomena involving rapid and heavy condensation are necessarily accompanied by electrical manifestations.

103. The earth may be negatively or positively electrified, as also the air and clouds may be possessed of either positive or negative electrification.

104. Clouds are never insulated from the earth.

105. We may suppose that a mass of comparatively dry air interposes itself between the earth and a large collection of clouds for a short time. In such an event, the positive electricity of the clouds induces negative electricity upon the upper surface of the mass of dry air, repelling the positive electricity to the lower surface of the mass. The positive charge induces a

negative charge upon the earth immediately beneath, and the two electricities are neutralized, leaving the superincumbent mass of dry air negatively electrified and consequently repelled by the earth.

106. The foregoing supposition is theoretically correct, but such a condition of the atmosphere does not exist.

107. The mass of dry air, if constant and stationary, would act as a sort of insulator or non-conductor between the clouds and earth. But the air is constantly in motion, and therefore the clouds also. The air is constantly changing its degree of moisture and the tension of its vapor. All of these changes and others are constantly and decidedly qualifying its degree of conductivity.

108. Electricity can always be detected in the upper regions of the atmosphere.

109. In clear weather atmospheric electricity is nearly always positive. In stormy weather the indications are both positive and negative, and about as frequently of one sign as the other.

110. Great variations are found to occur in electrical density in the lower regions of the atmosphere, owing to the rapid and marked changes in potential in the cloud regions.

111. Assuming the electrical density of the earth as constant, there are marked differences of potential as we recede from its surface.

112. Electrical density is greatest on elevated portions of the earth's surface; for example, on a mountain peak as compared with the plain below; on hills as compared with valleys.

113. In all conditions of the atmosphere there is a remarkable variability of electrical potential. As measured with the variability of other meteorological phenomena, there is hardly an element whose fluctuations bear any comparison, either in extent or rapidity.

114. All observations unite in showing that electrical potential is greater in winter than in summer; the most decided minimum being in May or June.

115. Diurnal variations indicate the presence of two maxima of potential, which on the average occur at the hours 9 A. M. and 9 P. M.

116. Precipitation from the under surface of a cloud or mass of clouds may be electrified with a sign opposite to that with which the upper surface is charged.

117. The combination of the particles of precipitation, whether of snow, rain, or hail, does not augment the quantity of electricity or affect the potential, although it may increase the electrical density of the mass.

118. The electricity of the clouds is constantly fluctuating through an interminable succession of changes in the electrical potential of the surrounding air and the neutralizing effect of the earth.

119. That form of precipitation usually most favorable to the increase of electrical potential is snow. If accompanied with high wind the gain is still greater.

120. Electrolysis is the decomposition of certain compound substances by the passage through them of an electric current. These substances are therefore called electrolytes.

121. Liquids (they must be conductors) are the only subjects which are electrolytic.

122. The vapor of water is not electrolytic because it is a gas. Therefore the assertion that its electrolysis produces the heat of the tornado is without foundation.

123. Electrolysis is the product of what is termed current electricity, while the electricity which is present in the tornado is called frictional. Therefore no feature of the tornado can owe its origin to electrolysis.

124. Every electrolyte must be composed of compound molecules. Even after electrolysis the anion and cation may still be possessed of a number of molecules of simple bodies. Every electrolyte in the liquid state becomes a non-conductor when solidified and thereby loses its electrolytic condition.

125. Pure water has never been electrolyzed because of its great resistance to electrolytic conduction. The purer the water the greater its electrical resistance. In fact, pure water must be acidulated in order to make its conductivity more susceptible.

126. All chemical compounds are not electrolytic, and even compounds containing the same components as electrolytes, but not in equivalent proportions, are therefore not electrolytes.

127. In an insulated conductor the algebraic sum of the two electricities which may be induced is equal to zero. But where the conductor has an independent charge the resulting force of the induction will be expressed by the algebraic sum of the force which would exist if there was no independent charge and the force due to the independent distribution without induction.

128. The forces of attraction and repulsion vary inversely as the square of the distance from the inductive source. Divide the distances by 2 multiplies the force by 2. Multiply the distance by 2 divides the force by 2.

129. The forces of attraction and repulsion depend upon the amount of the charge. The charge depends upon the size of the body and the distribution of the electricity.

130. In a good conductor the electric charge passes instantly from one molecule on another. In fact, the discharge of each molecule may be considered instantaneous. It is a moderate conductor or poor insulator. Each molecule may possess for a very short space of time positive electricity on one side and negative on the other.

131. In a good insulator the discharge is exceedingly slow, and therefore a high degree of polarization may be maintained for a considerable time. The above statements are in accordance with Faraday's theory of "induction by contiguous particles."

132. The peculiar sensations of what are termed "burning," "scorching," or "stifling heat," which are reported by those who experience the violence of the tornado's vortex, must be due to the latent heat of vaporization which is given off in great quantities by the extremely rapid condensation that attends the tornado as a constant feature. A numerical expression may be given to the above by stating that a pound of vapor of water at the temperature of 100 degrees centigrade will produce 536 degrees of sensible heat, upon being condensed at the same temperature.

133. The amount of latent heat liberated in the process of condensation depends upon the temperature at which the modification is effected. The lower the temperature (other things being equal) of the vapor the less the quantity of heat made sensible by condensation.

134. In the tornado the temperature of the vapor of water is considerably lower than given in the previous example, consequently the sensible heat is less when condensation takes place. But the enormous mass of vapor condensed in part overcomes this deficiency, and the total quantity of sensible heat which may be experienced will be quite sufficient to produce uncomfortable sensations.

135. With the sensation of heat there appears to be experienced a peculiar difficulty for breath. This effect is probably due to the extreme rarity of the air in the vortex consequent upon the violent centrifugal action of the currents.

136. The peculiar sensations of cold experienced in the path of the tornado may be due to marked differences of temperature between the interior of the tornado-cloud and the air surrounding it. The sensations as reported by observers appear to be relative rather than absolute. Observers always first experience a stifling heat and then a chilling cold. The latter condition never precedes the former. The cold is always encountered just after the period of maximum violence of the storm. A cold current sets in from the west and northwest in the wake of the tornado. The temperature of this current under ordinary circumstances would not produce a chilling effect, but because of the abnormal conditions in the tornado, the observer's first experience places him in decided contrast with that which immediately follows. The change is similar to what would be experienced in passing from the moist, hot air of a bath-room into the cold, dry air of an ice-house. In either case the extremes of temperature may not be marked, but the sudden change from one to the other produces a painful shock to the system.

137. Electrical forces always act in straight lines, while the forces of the tornado may be exerted in either straight lines or in those directions embracing the most complicated curves.

Can any manifestations of electrical force twist the body of a hickory tree several times about the same vertical or horizontal axis?

138. We have said that electrical manifestations *accompany* or *attend* the tornado, but do not *cause* the storm. This kind of electricity is called statical or frictional as opposed to voltaic or current electricity. The latter is believed to be the only form of electricity which will produce electrolysis. Experiments have been made with the electric spark in an attempt to produce electrolysis, but the efforts were not successful. The electric spark (statical electricity) will, under certain circumstances, produce what may be called a dissociation of certain compound substances, but this phenomenon can not be considered electrolysis.

139. Faraday estimates that the quantity of statical electricity required to decompose one grain of water is 800,000 times as much as would be required to kill a cat. Expressing this force in other terms, we find that the quantity of static electricity required to decompose a grain of water would, if it charged a cloud situated at a distance of 3,281 feet above the earth, exert an attractive force between the cloud and the earth beneath it of 1,497 tons. Suppose the area of the above cloud to be 50 by 38 feet, the attractive force is otherwise expressed as one ton per square foot of surface. This illustration of comparative electrical forces is not intended for one moment to argue that these conditions ever really exist in the atmosphere. The purpose is to show the comparative electrolytic properties of statical and voltaic electricities, and to make evident the absurdity of reasoning that the high temperature of the tornado vortex is due to the electrolysis of atmospheric vapor.

140. In explaining the electrical origin of the tornado and asserting that the electricity present acts as usual between two opposite polarities, the inference does not follow as maintained, viz.: That one pole being given it induces the opposite pole on the nearest point of matter adjacent to it. This assumes that the highest objects on the surface of the earth are subject to the greatest electrical influence simply because they are the *highest*. Now, it is admitted that elevation is a decided advantage in the

comparative influence of the electrical forces of attraction, but without another accompaniment *elevation* has no superiority. The object, high or low, must be electrically connected with the earth. The lightest or the most lofty of objects could not be moved from their foundations by the most powerful electric charge if they were insulated from the earth. The principle here involved is illustrated by that old electrical experiment of Volta's, by which pith balls were made to fly back and forth between two metallic plates oppositely electrified. The moment the lower plate is insulated from the earth the balls are repelled from the upper plate and remain stationary upon the lower one, showing that the force of attraction is lost the instant that electrical connection with the earth is broken.

141. Any method of reasoning which assigns tornado development to planetary influences is, equally with the electrical theory of their origin, without foundation. We have but to realize that in the formation of the tornado and other local storms of a similar character the entire action of all the forces involved, except the energy of the sun's heat, is embraced in that portion of the atmosphere within from two to three miles of the earth's surface. Any influence emanating from the movements, conjunctions, or other periodical mutations of the heavenly bodies, distant hundreds of thousands and millions of miles, can only reach an infinitesimal amount, and entirely inappreciable in its effect upon the atmosphere to produce local or general disturbances, especially near the earth.

142. It has been asserted that the conditions which give rise to the formation of the tornado-cloud result from the effect upon the atmosphere of the mere revolution of the planets in their orbits. That circular movements in the atmosphere are propagated and continued by such influences. The effect is likened to that which would result from the whirling in different directions in a large vessel of water of several globes attached to the same spindle. Upon withdrawing the globes after a number of revolutions, the surface of the water would be found covered with a network of eddies. The inherent fault of this simile is the fact that while the illustration provides for the circular movement of the bodies within the medium which is set in motion to give the

characteristic whirls or eddies, the subject of illustration, the planets, perform their revolutions, not in the atmosphere, the medium to be set in motion, but millions of miles away from it in another medium, concerning which little is known. The failure to properly apply the method of reasoning by analogy often leads the novice into making the most ridiculous assumptions. It would be more reasonable to assume that the revolutions of the planets give rise to the great disturbances of the atmosphere, embracing extended regions of country, which are known on the weather-map as "Highs" and "Lows," but even here the same difficulties operate, although not so extravagant as in the case of the tornado with its narrow path of a hundred yards or more.

143. Finally, the tornado is the result of an accidental condition of the atmosphere; and, therefore, it cannot be due, as many believe, to some periodical influence emanating from the movement or relative position of the planets, which conditions, of course, recur with the most exact regularity. When the tension between the opposing currents of warm and cold air suddenly and unexpectedly becomes broken at any point, centripetal action sets in and the funnel-shaped cloud soon appears, not through some mysterious and improbable agency, but by a reasonable and natural operation of well-known physical forces.

INSTRUCTIONS FOR OBSERVING WIND-STORMS.

The following is a full and complete copy of the "Tornado Circular No. 1, New Series," issued from the Signal Office at Washington for the guidance of persons who desire to aid in observing wind-storms. The entire circular is inserted here as a thing of great value. The questions are classified under headings, which briefly refer to the general character of the data desired; the details being covered by the questions themselves. Persons making observations for the purpose of forwarding them to Washington should number their communications according to the following arrangement: For example, "*Wind Direction No.* 6 —*Northwest*, 5:30 A. M." Observations with as full particulars as can be collated should be promptly forwarded to the Chief Signal Officer of the Army, Washington, D. C.

SUBJECTS AND QUESTIONS

DATE, TIME, AND CHARACTER OF STORM.

1. Give the year, month, day of month, and hour of day (hour and minutes, and A. M. or P. M.) when the storm occurred.

2. Did you have a storm on the above date; and, if so, what was the nature of it, and from what point of the compass did it approach?

3. When time of day is asked, give the same in hours and minutes, and state whether it is local or railroad time, and by what standard, viz.: Chicago, Detroit, Columbus, St. Louis, etc., etc.

4. What time of day did threatening appearances commence, in what portion of the horizon, and at what time were they the most decided?

5. The time of day when the tornado-cloud passed.

WIND DIRECTION.

1. The direction of the wind while the tornado-cloud was approaching.

2. The direction of the wind while the tornado-cloud was passing.

3. The direction of the wind after the tornado-cloud passed.

4. The direction of the wind during the forenoon of the day and up to the time of the first threatening appearance in the heavens.

5. The prevailing direction of the wind at this season of the year.

6. What was the direction and force of the wind when you first noticed the weather in the early morning? Give the hour of observation.

7. When direction of wind is asked, the direction of motion of the air-currents is meant, independent of the course or motion of the tornado-cloud. Always give the points of compass from which the wind comes.

TEMPERATURE OBSERVATIONS.

1. Was the day unusually warm and sultry? Give the maximum temperature, if possible, and state the hour at which it

was observed, together with the direction of the wind and the state of the sky existing at the time.

2. What was the condition of the temperature after the tornado-cloud passed? Did the air suddenly, or gradually, grow colder? Give the minimum temperature for that afternoon and evening, and during the night, with direction of the wind.

3. What had been about the average daily temperature, also the maximum and minimum, together with the accompanying direction of the wind, humidity, and clouds, for two or three days previous to the occurrence of the tornado and for three days succeeding its appearance?

MOTION OF TORNADO-CLOUD.

1. Describe the character and motion of the surrounding clouds before, during, and after the tornado-cloud passed.

2. Give the time of day at which the light or dark irregular clouds surrounding the tornado-cloud were in the greatest confusion, and describe the scene.

3. If you saw the tornado-cloud, describe or sketch it, and note particularly any change in motion or the successive stages of development during the time of observation.

4. Give the direction of the whirl of the tornado-cloud, as against, or with, the hands of a watch, face upward.

5. Give all the motions of the tornado-cloud which you observed, or which you heard that others had witnessed, as, for example: rising and falling, swaying from side to side, or whirling about a central axis, etc., etc.

6. Describe minutely the manner in which objects were carried inward, upward, and about in the whirling vortex of the tornado-cloud; how thrown outward, and from what portion of the cloud.

7. Give the direction of the course pursued by the tornado-cloud along its path of destruction in your locality, as, for example: N. 70° E.; E. 30° N., or E. 20° S., etc., etc.

8. Did the tornado-cloud remain in a vertical position as it traveled forward, or was the tail of it inclined; in what direction, and how many degrees from the perpendicular?

9. Give an estimate of what you consider the progressive velocity of the tornado-cloud; how many miles per hour. Give the data upon which you make the estimate, and why you believe your estimate to be reliable.

10. As the tornado-cloud approached, from what direction came the wind you first experienced, whether against your body or against the building within which you were situated at the time.

11. Try and give an estimate of what you consider the wind's velocity within the central whirl of the tornado-cloud, and also the data upon which you base this estimate.

12. In the passage of the tornado-cloud over a pond, lake, or river, carefully describe every particular in the disturbance of the water; how high into the air any portion of it was carried; if any fish, shells, stones, or the like, were carried out, and in what direction. Also state the exact position of the person, or persons, who witnessed the scene.

13. Were bits of leaves, mud, straw, grass, or the like, thrown against your building? If so, state on what particular portion or portions, and whether apparently thrown thereon with great force. If thrown upon the bodies of persons or animals, carefully state the circumstances.

FORM OF TORNADO-CLOUD.

1. How many funnel-shaped clouds did you see? Describe each, giving their relative sizes, shapes, and positions, and, if possible, a rough sketch of each.

2. Describe the color of the tornado-cloud; its density; how and when changes in color and density occur; the color and density of the bottom of the cloud as compared with the top; the existence of light and peculiar fleecy clouds over and about the upper portion.

3. Give the comparative size of top and bottom of tornado-cloud; note particularly and describe minutely any change in form when the bottom or tail reached the surface of the ground.

4. In observations upon the tornado-cloud, please note the angular height of the top of the cloud from the horizon, that is, above the plane of the horizon; also the horizontal distance from

the observer to the bottom of the tornado-cloud. Carefully estimate the angular height in degrees, and the horizontal distance in yards or miles.

HAIL OBSERVATIONS.

1. If a hailstorm, state whether the hailstones were large or small, of peculiar shape, and few or many in number. Give exact size and weight of some of the largest.

2. Did you examine the interior of any of the hailstones, and if so, how were they formed, and what did they contain?

3. If hail fell at intervals during the day, state the times of beginning and ending of each precipitation separately, together with the direction of the wind at each occurrence.

4. Was there any peculiar condition of the clouds at the time of the hail? If any strange feature was noticed, give details.

5. On which side of the tornado's path (to the N. or to the S.) did the hailstones appear to fall in the greatest quantity?

6. Did the hail fall before or after (how long) the tornado-cloud passed?

7. Did you notice any distinct peculiarity in the approaching or overhanging clouds from which the hail itself fell? Did the hailstones appear to drop from the funnel-shaped cloud, or from the surrounding clouds?

RAIN OBSERVATIONS.

1. Any rain, and did it fall before or after (how long) the tornado-cloud passed?

2. If any rain fell during the hailstorm, be careful to state whether it fell *before*, at the *time* of, or *after* the hail ceased. In case of the two extremes, give the interval in minutes.

3. On which side of the tornado's path (to the N. or to the S.) was the rainfall the heaviest?

4. If rain fell at intervals during the day, state the times of beginning and ending of each precipitation separately, together with the direction of the wind at each occurrence.

5. Any peculiarity in the size of the rain-drops, or in the quantity which fell?

ELECTRICAL OBSERVATIONS.

1. Was thunder or lightning observed, and if so, in what portion of the horizon, at what time of the day, and whether violent or otherwise?

2. Was lightning or other manifestation of electricity seen in the funnel-shaped tornado-cloud as it approached or passed, or in the dark, heavy clouds surrounding it to the N. and W.? If so, describe the appearance minutely.

3. Do you know of any one who made observations concerning the deflection of a magnetic needle during the day of the storm, especially while the tornado-cloud was passing a given point? If so, send his address, or give the result of the observations.

4. The terms *lightning* and *electric discharge*, as used in this circular, are synonymous.

5. How can one determine whether electricity has *any* influence in aiding the development and progress of the tornado, or is only an *unimportant* factor?

6. Is there any reason to suppose that the clouds approaching from opposite directions, preceding the first appearance of the funnel-shaped cloud, were oppositely electrified?

7. Did lightning tend to pass between the approaching clouds?

8. Did the motion of the approaching clouds appear to be accelerated at the moment of, or immediately following, any electric discharge?

9. Were electric discharges observed to take place in the initiatory whirl of the approaching clouds?

10. Were electric discharges observed to take place between the cloud-spout and the earth, while the former was yet at a considerable elevation in the air?

11. Is there any competent evidence to show an increase of electrical manifestation upon the descent of the cloud-spout to the earth?

12. Was lightning observed in the heavy bank of clouds along the western horizon after the tornado-cloud had advanced beyond this cloud region to the eastward?

13. Are electric discharges which take place in the bank of clouds along the western horizon visible to an observer situated

to the eastward and in advance of the approaching tornado-cloud?

14. Can flashes of lightning which issue from the clouds along any portion of the western horizon be seen through any portion of the tornado-cloud? What portion? May not the flashes *appear* as if passing through the tornado-cloud from top to bottom, when really they are among distant clouds? It is important to determine whether the flashes of lightning, sometimes reported as appearing in the tornado-cloud, are not the result of an optical illusion.

15 What portion of the tornado-cloud presents the lightest color?

16. Cannot flashes of lightning be readily seen to descend to the earth at the *right*, *left*, and *rear* of the tornado-cloud, but evidently not emanating from it?

17. Does the upper portion of the tornado-cloud at any time present a glowing appearance, like the colors of a brilliant sunset?

18. Does any portion of the tornado-cloud ever present the appearance of sunlight passing through fine mist or rain-drops?

19. Always note the absence or appearance of the sun (whether obscured by clouds or not) while making observations upon the tornado-cloud. Give the position of the tornado-cloud with respect to the sun.

20. Note the condition of the sky between the tornado-cloud and the horizon at the *right*, *left*, and *rear*—clear, fair, or cloudy? Describe carefully.

21. Were "balls of fire" observed to accompany the tornado-cloud at any stage of its progressive movement? Did they appear to come from the tornado-cloud, or surrounding clouds? If from the former, from what portion of it, under what conditions, and with what result? Reply to this entire question very carefully.

22. What effect had the tornado upon small vegetation and the foliage of trees? How long after the tornado passed before there was observed any brown or seared appearance of leaves and stems, or any change of color on the trunks or limbs of trees or shrubs where the bark was broken or peeled off?

23. In the event of death or injury to any person or animal, observe very carefully whether the effect resulted from electrical discharge or the force of the wind.

24. In the destruction or removal of any object within the path of the tornado, observe very carefully whether the effect resulted from electrical discharge or simply the force of the wind.

25. During the progress of the tornado does the air appear to rush into the cloud vortex from all points of the compass, or does it advance from only two points, viz., *northwest* and *southwest?* This information can probably be secured either by witnessing the passage of the tornado-cloud or carefully examining the disposition of the débris after the storm has cleared away. Light winds occurring on one or more sides of the center should be recorded as well as the destructive winds.

26. Observe whether the débris in the tornado's path appears to have been thrown down and carried about by the action of a continuous wind, or was the distribution the result of separate winds, operating successively in a direction veering around from right to left.

27. In the incipient stages of the cloud-spout does the air appear to rush in from all sides towards the point of inception, or does the air come principally from the *northwest* and *southwest?* This information can probably be secured by observing the formation of clouds and their directions of movement, carefully distinguishing between the several strata.

28. If possible, carefully determine whether the energy of the tornado increases or gradually diminishes after it has been perfectly formed. To ascertain the facts in this case it will probably be necessary to make an examination embracing the entire path of the tornado, or the larger portion of it.

29. Can the roaring, which always accompanies the tornado-cloud in its passage over the country, be readily distinguished from ordinary thunder? Is *thunder* ever distinctly heard as emanating directly from the tornado-cloud?

30. Carefully examine buildings, trees, and other objects which have been acted upon with marked severity by the tornado, and ascertain if there is good evidence of electrical action.

31. Try and secure some observations upon the variability of atmospheric electricity in the immediate vicinity of the tornado's path. What effect was observed in telegraph offices? How were the telegraph lines affected? To what extent was the magnetic needle affected?

32. The effects of lightning are: rupturing and scattering of imperfectly conducting substances and the inflaming of those which are combustible; heating, reddening, melting, and volatilizing of metals; the production of shocks more or less severe and often fatal to the lives of men and animals, and the production of ozone, causing a sulphurous odor.

In conducting an examination over any portion of the tornado's path, carefully determine whether any of the above effects are present.

33. Report all damaging effects by lightning, whether connected with a tornado or attendant upon some general storm. Describe the conditions of each case prior to the damage and then follow these facts by carefully stating all the particulars of injury. Make a personal examination of each case when practicable. State whether the object damaged was protected from injury by lightning in any manner and how. Note the disposition of débris about the *object* damaged, or surrounding its *location*, if entirely destroyed.

34. Of a building or tree, note its height above the ground and its position respecting other objects.

35. Of persons or animals, describe their location at the time of damage with respect to other objects, and in case of persons, the character and condition of their clothing.

36. Give the hour of day when damage occurred. Send newspaper items regarding the damage.

METEOROLOGICAL OBSERVATIONS.

1. If no *tornado* occurred at or near your station, please state whether you experienced any sort of a storm, and give the nature of it.

2. Did you hear a roaring noise on the approach of the storm, and if so, state in what direction, the intensity, or any accompanying peculiarity?

3. Did you notice any peculiar odor in the atmosphere during the passage of the tornado-cloud, and what was it like?

4. Do you know any one who made observations on the presence of ozone in the atmosphere on the day of the storm? If so, send his address or give the result of his observations.

5. What was the condition of the sky when you made your first observation in the morning? Was it cloudy, three-fourths cloudy, one-half cloudy, one-fourth cloudy, or entirely clear?

6. What was the direction, or directions, in which the clouds were moving at the time of your first observation?

7. What time of day did it commence to cloud up, and in what quarter of the heavens?

8. Describe the character of the clouds when the first threatening appearances began.

9. Give the time of day, the quarter of the heavens, and the character of each formation, if there were frequent and sudden changes in the development or grouping of the clouds.

10. How many days previous did you notice any indications of an approaching storm, and what were those indications?

11. Did you observe the form of cloud commonly called "mare's tails" (cirrus); in what part of the heavens and how many days previous?

12. In what quarter of the heavens did the passing storm seem to be the heaviest?

13. What time of the day did the first threatening appearances commence, and in what portion of the heavens?

14. How did the day open?

15. Did the clouds gradually thicken on this day, or was there a sudden and portentous banking up of them in the W. during the afternoon?

16. Did the clouds appear to gather near the earth and extend in irregular forms to great heights, or was there a heavy, dark mass, with comparatively regular outlines, hanging low down in the W.?

17. What time during the day, and in what portion of the heavens, did you notice small light or dark clouds, if any, driven swiftly by the wind? Tell how they moved, from what direction or directions they came, and where they seemed to concentrate.

18. In describing clouds, especially where they are peculiar or portentous in appearance, aside from indicating character or formation, give the most striking colors and state how they blended with each other.

19. In the event of the occurrence of any storm, state whether it passed your location by either the N. or S. point, or directly overhead.

20. What time of the day did you notice any decided change in the temperature, and what was the extent of that change?

21. In making a statement concerning any feature of the weather during the day, be careful to give the hour at which the condition referred to was observed.

METEOROLOGICAL INSTRUMENTS.

1. If you, or any of your neighbors, have meteorological instruments, give the readings of the thermometer and barometer, direction of the wind, and the hour of observation, for two days before, on the day of the storm, and for two days thereafter.

DRAWINGS, SKETCHES, AND PHOTOGRAPHS.

1. If possible, try to represent the tornado-cloud by a rough sketch, as also the dark and irregular clouds surrounding it.

2. Give the direction and distance from your house to your various farm buildings, if possible drawing a plan of the same and indicating the points of the compass. This plan need only be a rough sketch.

3. Give the dimensions of your buildings, and state the character of each as to whether they are log, frame, stone, or brick, and weak or strong.

4. In drawing a plan of your buildings, indicate the position of the tornado's path with respect to each of them and the direction in which the tornado-cloud moved.

5. If possible, please furnish photographs, sketches, or printed cuts representing the tornado-cloud or some evidence of its destructive power. They are very desirable. If you cannot furnish them, perhaps you know of some one who can. This office is desirous of obtaining sketches of clouds, however rough and imperfect. If in any way you can readily depict upon paper the unroofing, overturning, or crushing of a building, the destruction

of an orchard, uprooted or twisted trees, or the falling or twisting of timber as the tornado-cloud swept through the forest, it will be valuable. Perhaps you know of some one who witnessed these scenes, or part of them, and who would be willing to illustrate them.

6. Sketches of clouds of peculiar destructive effects, of hailstones, of anything that will illustrate any distinguishing feature of the storm's violence, are very desirable.

GENERAL DESTRUCTION TO PROPERTY.

1. How far, and in what direction, are you situated from the center of the path of destruction?

2. Give the maximum and minimum width, in yards or rods, of the path of destruction in your vicinity, and state, if you can, whether in examining that path it was found that on the S. side of the center the sweep of destruction was broader and more irregular than on the N. side, or if any other difference existed between the two sides.

3. In giving your distance from the center of the path of destruction, indicate the same in miles and parts of miles or rods, stating the amount in northing and easting, northing and westing, southing and easting, or southing and westing, estimated along section or township lines.

4. In all descriptions of the tornado's path, in giving any particular destruction in it, or in detailing your experience while the tornado-cloud was passing, be careful to state on which side of the center (to the N. or to the S., and how far) the damage occurred, or you were situated while a witness of the storm.

5. In the destruction of any building, whether unroofed, overturned, moved from the foundation, racked, or otherwise damaged, be very careful to state how the destructive force operated. Did the wind or tornado-cloud, or whatever you may term the force, cause the damage by *pulling*, *drawing*, or *sucking* the building, or any portion of it, inward to the center or outward from the center of the storm's path? Apply this same question to the pulling of fence-posts, uprooting trees, moving of machinery, or other heavy objects or animals. Did the destructive force operate as an ordinary wind in any sense, whether such wind be gentle or

violent; or, rather, was this *force* some mysterious, irresistible power, impelling an object (no matter how large or weighty) to *move*, as if the pressure of the atmosphere in front of it, or round about it, suddenly gave way, without your knowing how? Did buildings *suddenly* seem to totter; trees in an *instant* bend to the ground; the pressure of the air against your body give *way* all at *once*, or small objects move *swiftly* into the air or over the ground, and yet all this happen without *apparently* any *wind?* Take great care in giving facts concerning this point.

6. Give an estimate of the number and kind of buildings destroyed.

7. Give a similar estimate of the total valuation of property of all kinds destroyed.

8. Give the length and width of the tornado's path which passed through your section of the State.

9. Give the position of your house with respect to the nearest post-office, indicating the same in miles and parts of miles or rods; state the distance in northing and easting, northing and westing, southing and easting, and southing and westing, estimated along section and township lines.

10. State in detail and separately the damage to each building; what portion or portions were taken away or injured; how far and in what direction they were moved bodily; what portion of each was first struck by the wind, and how far and in what direction the débris was carried. Be very careful to give the exact position and peculiarities of structure of the buildings which were not damaged, although standing near those which were destroyed.

11. In the damage or destruction of each or any building, state particularly how far and in what direction any portion of them was carried a considerable distance.

12. If any object was carried a long distance by the force of the wind, state where and what it came from; its dimensions; its shape; probable height to which transported in the air; whether driven into the ground or not, how far and into what kind of earth.

13. State whether articles of clothing, fowls, or animals were carried into the air, to what height, to what horizontal distance, and in what direction.

14. Give detailed destruction of furniture contained in the house and of farming implements in and about the barns.

15. Be particular to note any evidence of the wind's extreme violence, as in the lifting of heavy objects; the twisting of trees or heavy pieces of timber; pulling up of fence-posts; removing heavy stones, etc., etc.

16. With regard to destruction in orchards, among shade-trees, and in forests, be particular to give the direction in which the trees lie; how they lie on the two sides with regard to each other and to the center of the path of destruction; any special acts of violence in the twisting, uprooting, or breaking off of heavy timber; give circumference of large trees, height above ground where broken off, and dimensions of earth and roots where notably large trees were overthrown.

17. In general, when giving the position of any person or thing with regard to the center of the path of destruction, state the distance in feet or rods, and the direction, as N. or S.

18. Give the maximum and minimum width, in yards or rods, of the path of destruction in your locality.

19. Did you notice any peculiarity with the manner in which small objects were suddenly removed from around about buildings, as if sucked in by the advancing cloud?

20. Did you notice any peculiarity in the falling of trees as tne tornado-cloud advanced upon them? Were they whipped about and bent to and fro as in a heavy wind, or were they drawn steadily inward toward the center on both sides, as if by some mysterious but irresistible force?

21. How many rods of fencing (stating kind) did you have blown down; in what direction were the N. and S. fences carried; what was the direction in which the E. and W. fences were carried?

22. Give an estimate in money value of the loss to your property occasioned by the tornado, the number of acres of timber you had destroyed, and the number of fruit-trees you had uprooted or broken off.

23. Be particular to give the exact position, also the dimensions and probable strength and weight, of small objects which

were not moved from about large buildings, although the latter were entirely destroyed.

24. In examining the path of destruction, did you find any difference between the N. and S. sides of it? Which side was the widest; which the cleanest cut; which the most irregular and jagged along its outer edge; on which side were narrow paths of destruction cut inward toward the center?

25. In describing the path of destruction, be careful to note where the tornado-cloud left the ground, where it again descended, the length of the interval, and the topography of the earth at the points of ascension and descension. Also state whether the hail and rain continued to fall after the tornado-cloud rose from the earth and disappeared in the overhanging clouds.

26. Estimate the time in minutes or seconds during which the tornado-cloud was committing the destruction at your buildings or in passing them at a safe distance.

27. In the destruction of your buildings, did you notice anything in the disposition of the debris after the tornado-cloud passed that would indicate the effect of an explosion, as, for example, the sides and the ends of a building being thrown outward and the roof carried off or let down upon the floor?

28. Where trees were overturned and wrenched or twisted by the force of the wind, describe minutely how and in what direction the twist runs—that is, its direction, as with or against the hands of a watch. Perhaps you can compare it with the bit of an augur or indicate the same by a rough pencil sketch. Also state what portion or portions of the tree were twisted, and what the kind of timber in the case of each tree so affected.

29. Observe carefully where the tornado-cloud passed through forests, and state on which side of the tornado's path (to the N. or S.) the trees were broken off at a considerable height above the ground; the maximum and minimum height; general size of trees so affected; kind of timber, and whether broken square off or twisted. Try and illustrate the path through the timber by a pencil sketch showing the various directions of the prostrated trees. Indicate the points of compass.

INJURY TO PEOPLE AND ANIMALS.

1. State the number, kind, and in what manner, stock were killed or injured, and whether at the time of the storm they were in or without buildings. Also narrate any miraculous escapes of life.

2. With respect to your family, give the whereabouts and condition of each person on the approach of the tornado, and also after the tornado-cloud passed. Give age and sex of each person, and particularize the character and extent of injuries to each. State very carefully the distance and direction in which any of the persons were carried, and also narrate any miraculous escapes of life.

3. In describing the injury to any person, animal, or object, never fail to give the distance and direction of such person, animal, or object from the center of the path of destruction at the time the tornado-cloud passed.

4. Estimate the number of persons killed and wounded along the entire path of the storm.

5. Give a similar estimate of the number and kind of animals killed or injured.

WIND FORCE AND VELOCITY.

1. To indicate the *force* of the *wind*, use the following scale, expressing the velocity in miles per hour, if you have an anemometer; or if not, estimate the same by employing the appropriate terms here given.

0	Calm.
1 to 2 miles per hour	Light wind.
3 to 5 miles per hour	Gentle wind.
6 to 14 miles per hour	Fresh wind.
15 to 24 miles per hour	Brisk wind.
25 to 39 miles per hour	High wind.
40 to 59 miles per hour	Gale.
60 to 79 miles per hour	Storm.
80 miles per hour and above	Hurricane.

2. Where it occurs that a heavy body has been transported by the force of the wind, please give weight, dimensions, and form; also distance carried.

3. What was the highest velocity of the wind in miles per hour, and the direction from which it came? Approximate the velocity if you can do no better.

4. What was the time of day when the maximum velocity occurred.

5. Can you give the temperature at the time the highest wind velocity occurred? If not, say whether it was warm or cold.

6. In the event of any storm whatever, give the direction and force of the wind while the storm was approaching, while the storm was passing, and after the storm passed. If a number of storms occurred on this day, give particulars of each.

7. At what time, or times, of the day did you notice any freshening of the wind, and what was the direction at each occurrence?

8. It is both a matter of great interest and much value to determine high-wind velocities such as are common to the violence of the tornado. The important question involved is the relation of velocity to pressure. This relation varies among other things with the altitude above the earth's surface, the form and size of surface of impact, and the elements of friction. Experiments have been made with square and spherical surfaces of very small dimensions, giving certain results, which for purposes of application have been expressed in the language of simple formulas. For surfaces of large extent application of these formulas will give approximate results, but the error for ordinary purposes may be ignored.

For square surfaces at the earth's surface:—

$P = (0.0027\ A\ V^2)$.

P = pressure of the air in pounds per square foot.

0.0027 is the constant determined, theoretically.

A = the area in square feet of the surface against which the wind blows.

V = the velocity of the wind in miles per hour.

For square surfaces at any altitude:—

$$P = 0.0027\ A\ V^2 \frac{P}{P_0\,(1 + Lt)}$$

The terms of this expression have the meaning as given in the first formula, except the fraction $\frac{P}{P_0\,(1 + Lt)}$ which is explained as follows:—

P = the pressure at the upper station.

P_0 = the pressure (standard) at sea-level or lower station.

$1 + L\,t = 1 + 0.003665\,t$, t being the temperature of the air at the time of observation, and 0.003665 being the co-efficient of the expansion of air for one degree at a constant temperature and pressure.

All measurements of surfaces should be made with the utmost care. Wherever the object acted upon is not placed at right angles to the direction of the wind, the exception should be noted and the angle measured and reported. In cases where stone shafts are broken off by the force of the wind, all of the circumstances should be carefully described. Note particularly if the broken surfaces are chipped, and if so, to what extent.

The following table furnishes the means of comparing pounds pressure per square foot with velocity in miles per hour in accordance with the terms of the formula previously given.

$$P = .003\ A\ V^2;\ \text{assume } A = 1 \text{ sq. ft.}$$

Pressure pr. sq. ft.	Miles per Hour.									
	Units.									
Tens	0	1	2	3	4	5	6	7	8	9
	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles	Miles
0	0	18	26	32	37	41	45	48	52	55
1	58	61	63	66	68	71	73	75	77	80
2	82	84	86	88	89	91	93	95	97	98
3	100	102	103	105	106	108	109	111	113	114
4	117	117	118	120	121	123	124	125	126	128
5	129	..	..	..	..	..	..	..	..	..

PAST TORNADOES OR "WINDFALLS."

1. If you recall the occurrence, in times past, of any violent hailstorm in your State, give the place, year, month, day of month, hour of day, direction of the storm, maximum and minimum width of path in rods or miles, size and shape of hailstones, and a narration of the destructive effects.

2. If you recall the occurrence, in times past, of any other tornado in your State, give year, month, day of month, hour of day, the direction of the course of the path of destruction as pursued by the tornado-cloud, its length in miles, average width of destructive path in yards or rods, maximum width, minimum

width, and, if possible, the hour of beginning and hour of disappearing of the tornado-cloud.

3. The following questions relate to old "land marks" through the forests, well known by the name of "windfalls." In "early times" violent local storms of wind, rain, and hail swept over portions of newly settled country, marking their pathway by fallen timber, which in the heavy forests was cut down in swathes or lanes, narrow but well defined. You are invited to furnish such information as you can conveniently concerning this subject. It is not presumed that any one person will be able to answer every question propounded. Dates are especially important, but it is realized that to authenticate their accuracy will, in many cases, be difficult. Always furnish dates when any are reported, even though doubtful, and note the doubt. Perhaps you can associate the occurrence of the storm with some prominent event in the history of county or State, and thereby remove obscurity concerning the date. Some of the questions call for data which anticipate the examination of records:—

QUESTIONS.

4. Date of storm: year, month, day of month, and time of day.

5. Location of storm's path: give distance in miles and fractions of a mile to the nearest post-office or county court-house.

6. Direction of storm's path: by points of compass, expressed in degrees, if possible.

7. Width of storm's path: average width in rods or yards.

8. Length of storm's path in miles and fractions of a mile.

9. Character of timber through which the storm passed, and the approximate amount of destruction.

10. Describe the disposition of the débris in the path of the storm. How was it disposed with reference to the north and south sides of the path?

11. Was the storm accompanied by an unusual roaring noise? Describe it.

12. Any hail or rain? Describe the character of the precipitation.

13. Describe the form of the storm-cloud and its peculiar motions, especially any motion about its axis.

14. Was there any display of electricity accompanying the storm? Describe fully, and note any destruction by this force.

15. Was the day of the storm unusual with respect to temperature, variability of wind direction, humidity, and cloud formation?

16. What were the general atmospheric conditions for the several days preceding and succeeding the day of the storm?

17. Was there any unusual odor observed in the atmosphere on the day of the storm? Describe it.

18. Report any loss of life and the destruction of buildings.

19. Furnish authentic record (written or published) of storm when possible.

20. For how long a period did evidences of the storm remain?

21. What speculations have been indulged in concerning the nature of "windfalls," and the causes which resulted in the formation of such paths of destruction?

22. In the event of copying data from permanent records (books, newspaper files, etc.), give name of publication, volume, page, and date of issue.

23. Enumerate and describe particular and peculiar evidences of the storm's violence, such as: objects carried long distances; scars upon trees or other objects; bowlders moved from their beds; trees torn from the earth or twisted off near the ground; pieces of timber imbedded in trees or stumps, or in the earth, etc., etc.

24. Furnish post-office address of any person who may be possessed of information concerning "windfalls."

25. Do not fail to furnish any clue, however slight, which may eventually lead to a discovery of the complete record of a "windfall."

MISCELLANEOUS QUESTIONS.

1. If not individually prepared to answer any or all of the above questions, please call to your aid such persons as may, in your judgment, be able to render you assistance.

2. Send any newspaper article concerning this storm or others which have occurred during this season.

3. Give name and address of any one in your State who is in the habit of keeping a meteorological record.

4. If possible, try and secure the co-operation of some intelligent person, who, at the time of its occurrence, was situated either in the path of the tornado or on the outer edge of it, and who will be willing to furnish a narrative of the result of his observations.

GENERAL INSTRUCTIONS TO VOLUNTARY TORNADO REPORTERS.

1. The following instructions are issued for the specific observance of voluntary Tornado Reporters for the Signal Service:

2. Report the occurrence of all local wind-storms.

3. Reports are to be rendered in accordance with the terms of this circular.

4. All reports should be rendered as soon as possible after the occurrence of a storm.

5. No instruments are absolutely needed but the wind-vane and the thermometer. This office can furnish a standard thermometer (compared and corrected) at cost. An ordinary thermometer which can be procured in any village, at small cost, will have to answer if a standard instrument cannot be purchased.

6. A price-list of standard meteorological instruments, apparatus, text-books, forms, and publications is furnished to all Reporters in Tornado Circular No. VI.

7. The back of Tornado Circular No. V. (new series) indicates the character of the observations to be taken and recorded.

8. Whenever, in the judgment of the Reporter, the atmospheric conditions at his station are such as to portend a violent storm, he should immediately commence observations and record them on back of Tornado Circular No. V. (new series).

9. The only observations imperatively necessary are temperature, wind direction, and clouds. Humidity is desirable, but an additional thermometer of standard pattern (to form the hygrometer) would be required.

10. For observations on wind direction a wind-vane can be furnished by this office at cost, but it is rather expensive. In lieu of this, it is sufficient to erect a cheap vane upon some

prominent structure near at hand, where the instrument will not be affected in its indications by surrounding objects. It is presumed, however, that Reporters will not need to resort to this expense, as at every station suitable wind vanes will very likely be found, either upon residences or public buildings, that will answer every purpose.

11. Cloud directions must be observed independently of the wind-vane. It will require some experience to observe these directions accurately. There may be instances in unusual storms where three or more strata of clouds will be found coursing in as many different directions. It is very important to distinguish the various directions, and describe the character of the clouds in each current. The directions are best observed by comparing the clouds with some fixed object above the observer, such as a distant steeple or tree-top, or the cornice of a building.

12. The wind is an important element in tornado investigation. Each Reporter is requested to use the best means at hand for ascertaining the force of the wind in any particular instance, and clearly state the methods by which his results were derived. The strength of the wind is expressed in two ways—either (*a*) by descriptive terms, such as light, gale, hurricane, etc., see the tables of terms of this circular, or (*b*) numerically, by one of two methods: (1) the force or pressure in pounds per square foot; (2) the velocity in miles per hour. These numerical methods imply the use of anemometers, but in no case should the observer omit the descriptive terms. Observers who experience the very destructive winds of the tornado's vortex should also give such measures of the weight and dimensions of heavy objects blown about by the wind as will give a basis for calculating the force required to move them.

13. Hourly observations are desirable for the eight (8) hours immediately preceding a storm, and for the five (5) hours directly succeeding it. Under the usual conditions for local wind-storms this division of time would bring the first observation about 8 A. M. and the last about 9 P. M. But these times will differ more or less according to the peculiarities of each storm.

14. Observations at the following hours are desirable for every day on which the conditions are even slightly favorable for tor-

nadoes: 7 A. M., 10 A. M., 12 noon, 2 P. M., 4 P. M., and 8 P. M.

15. Where Reporters are possessed of additional instruments to those here considered necessary, they may report the observations taken with such instruments, and blank space will be found on back of Circular No. V. (new series) for their record.

16. If Reporters have no instruments, and cannot afford to purchase any, this fact will not wholly incapacitate them for the duties involved in their position. A large proportion of the most important results are to be accomplished by simple observation and careful examination.

17. Reporters are informed that suggestions from them relating to any improvement in the work of investigation will be gladly accepted and carefully considered.

18. Further instructions will be issued from time to time as the exigencies of the work demand.

19. It is needless to place postage stamps upon the penalty-stamped envelopes and wrappers furnished by this office. The printed stamp on the upper right-hand corner of the envelope or wrapper is all-sufficient for mailing any communication or printed matter relating to official duties.

20. Tornado Circular No. V. (new series) will be used in connection with the general instructions herein contained, which will govern the conduct of tornado investigation.

21. A special description of every tornado is desired. The following remarks are submitted as helpful in guiding the observer: If a complete account of the entire track of a tornado is undertaken, let the observer be very careful to state as accurately as possible the place of beginning. This location is not necessarily where the tornado-cloud *first* descended to the *earth* (although it may be), but, more truly, it is that particular spot or portion of country over which (perhaps at a great height above the earth) the funnel-shaped cloud was *first* seen to *form*.

22. Having found the place of commencement, carefully ascertain all the preliminary conditions of atmospheric changes existing prior to the development of the tornado-cloud. In determining the exact locality of final disappearance, exercise considerable vigilance, for you may most easily be deceived. It is a characteristic feature of the tornado-cloud to rise suddenly from

the earth, and, continuing its northeastward course in the lower regions of the atmosphere, again reaching *terra firma* after an interval of several miles. You may find a number of these gaps along the tornado track you are examining, but do not mistake them for points of termination; rather look upon their appearance as suggestive of a subsequent re-appearance rather than disappearance. If these gaps occur in consecutive order as to time and place, pursuing, when taken together, a northeastward trend, and the difference in time of disappearance and re-appearance at each interval accounts for the passage of that interval, there can be no doubt of their forming disconnected parts of one and the same tornado track. The invariable accompaniment of a tornado is the hailstorm, which *precedes* its first appearance, and *succeeds* its final disappearance. This characteristic should be carefully watched for and any peculiarity minutely recorded.

23. Tornado features are peculiar in that they are *particular* rather than *general.* In regard to information, the test of desirability is reached, not so much by the *quantity* as the *character* of the data given. It is absolutely necessary to success, in securing precisely the information desired, that every observer should have at his command a code of definite instructions. By this means he will realize the necessity for the various lists of questions, their independent use, and prepare himself to undertake an intelligent examination of the tornado's path. It is not expected that every observer will find it possible to answer all the questions in any of the lists, because of the necessarily imperfect opportunities for observation incident to each locality. It is assumed, however, that if the conditions for observation were complete, every question could be readily answered.

24. The path of the storm should be divided by longitudinal lines into three portions parallel to the direction of progress: these will be designated as the center belt, the right side, the left side. These latter may be subdivided into belts of greatest or least disturbance.

25. Wherever reference is made to areas of destruction, or where prostrations are described, the part of the path in which the destruction occurred, or in which the débris was found, should always be mentioned.

26. To avoid confusion, no terms should be used to indicate the sides of the tornado track except "right" and "left."

27. The direction of all prostrated objects should be carefully given; if they have subsequently been moved by a force different from that which threw them down, or should the same force continue to act in successively different directions, such separate causes should be carefully distinguished.

28. The track of the tornado should be examined continuously throughout, and not here and there. The examinations should also be carried beyond the path of greatest violence; for, although no trees or houses may have been there destroyed, valuable evidence to show the mode of action can often be obtained.

29. Groups of trees lying upon each other should receive careful attention, and distinctions should be made between the top and bottom prostrations, and their several directions.

30. The topography of the ground over which the tornado has passed, and especially of that where destruction begins, should be observed. The comparative destruction on hilly and level ground should also be noted.

31. The atmospheric conditions before and after the appearance of the tornado, especially the presence of a thunder-storm, its severity, extent, and the contrasts of temperature north and south of the central area should be ascertained.

32. When prostrations are described on either side of the storm's track, or at the center, their relative positions, either respecting each other, the sides of the storm's path, or the center, should be stated.

33. The distance at which the surrounding currents of air are sensibly influenced by the cloud vortex ought to be determined, and also it should be noted whether or not any previously existing currents were immediately, or during the passage of the tornado, changed in their direction.

34. The currents of air on the two sides, and their relative directions and forces, should be carefully mentioned; also the currents of the center, whether upward, downward, or rotary.

35. Any unusual manifestation of force on either side of the track, the width and direction of the path of destruction, the character of the ground passed over, and also of that in the im-

mediate vicinity, and the direction, force, and temperature of currents of air should be given.

36. All explosions, the side on which they occurred, the direction and force of the wind at the time, and the character of the ground in their vicinity should be noted.

37. The place, date, time, and direction of the tornado are essential.

38. Observers should state the width and length of the track, giving, in the former instance, not only the entire breadth of the path of destruction, but of that part over which the greatest violence was exerted.

39. The velocity and duration of the storm, and the shortest time it consumes in passing any one point, are important facts.

40. The form of the tornado-cloud, its motion, direction, and velocity (estimating the latter approximately, if it cannot be determined accurately, by its action upon surrounding objects) should be given.

41. All air-currents which have been instrumental in directly causing destruction are important facts.

42. The direction and velocity with which the clouds, if there were any, were seen to approach before the beginning of the tornado, or any strange and violent agitation of the atmosphere noticed at the time, ought to be noticed.

43. The appearance and disappearance of the cloud vortex, the character of the section of country over which it disappears, and the conditions of the surface at the points of its departure and return should be noted.

44. The occurrence of thunder and lightning, and all evidences of electrical action, particularly within the tornado-cloud, should be given.

45. Particular attention should be paid to the peculiar rumbling noise attending the progress of the tornado, its duration, intensity, and the distance at which it can be heard.

46. The precipitation of hail and rain, the time of its occurrence, whether before, after, or during the passage of the tornado-cloud, the side on which it fell, and the direction of the wind at the time, are necessary elements of the investigation.

47. Efforts should be made to gather all available data regarding cloud formation, so that when opportunity is offered any peculiar development may be preserved by means of a sketch made at the time the information was obtained.

48. In all attempts at sketching a tornado-cloud, particular attention should be given to illustrating the peculiar whirl of the cloud, so that the sketch shall show whether the direction was from right to left or the reverse.

49. In all sketches of whatever nature, the supposed center of the storm's path should always be indicated by a long arrow pointing in the direction of the storm's progressive movement, so that the relative position of the objects acted upon as compared with that of the tornado's track may be known.

50. Every effort should be made to obtain temperature records, particularly where observations have been taken on opposite sides of the storm's path; the time of day and the accompanying wind direction are indispensable facts in connection with these observations.

51. It is of great importance that trustworthy data concerning the prevailing direction of the wind over the section of country traversed by the storm (together with the temperature), for at least ten days before the storm, should be obtained.

52. In entering upon the work of investigation, it is necessary that the observer begin his labors as near as possible to the supposed origin or first appearance of the storm, and then trace the phenomena in regular order.

Such method will often provide the explanation of anomalous effects, and materially assist him in following a train of sequences, watching the successive disclosures of the various features of cloud formation and attendant wind directions.

Much or most of this valuable information would be lost or seriously confused by any other mode of examining the storm's track.

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Prepared under the direction of—

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TORNADO INVESTIGATION.

Some of the results sought to be attained by a systematic study of tornadoes may be briefly given as follows :—

(1.) To determine the origin of tornadoes and their relation to other atmospheric phenomena.

(2.) To determine the geographical distribution of tornadoes and their relative frequency of occurrence in different States, and in different parts of the same States.

(3.) To determine the conditions of formation, with a view to the prediction of tornadoes.

(4.) To determine the means of protection for life and property.

(5.) To determine the periodicity of the occurrence of tornadoes, and their relative frequency by seasons, months, parts of a month, and time of day.

(6.) To determine the prevailing characteristics of tornadoes.

(7.) To determine the relation of tornado regions to areas of barometric minimum.

(8.) To ascertain yearly the loss of life and property in the various tornado districts, and its effect upon the industries of the people.

(9.) To ascertain the influence of topography upon the occurrence and movement of tornadoes.

(10.) To determine the influence of rainfall and forests upon the development of tornadoes.

(11.) To ascertain the relations of tornadoes to hailstorms, thunderstorms, and hurricanes. . . .

The following are most of the features of map study that must receive consideration in the preparation of a tornado prediction for any day :—

(1.) Barometric Trough. Region. Ratio of Axis. Pressure. Departure from Normal.

(2.) Central Area of Barometric minimum. Region. Pressure. Departure from Normal.

(3.) High Contrasts of Temperature. Region. Gradient.

(4.) High Contrasts of Cold Northerly and Warm Southerly Winds. Region.

(5.) High Contrasts of Dew-point. Region. Gradient.

(6.) Heaviest Lower Cloud Formation. Region. Kind.

(7.) Opposing Movement of Lower Clouds. Region. Directions.

(8.) Coincident Movement of Upper and Lower Clouds. Region. Direction.

(9.) Opposing Movement of Upper and Lower Clouds. Region. Direction.

(10.) Opposing Movement of Lower Clouds and Winds. Region. Direction.